ROUTE DESCRIPTIONS USING MAPS, PHOTOMAPS, AND IMAGERY: AN EXPERIMENTAL ANALYSIS

by

MAUREEN ANN KELLEY

A DISSERTATION

Presented to the Department of Geography
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

March 2013

DISSERTATION APPROVAL PAGE

Student: Maureen Ann Kelley

Title: Route Descriptions Using Maps, Photomaps, and Imagery: An Experimental Analysis

This dissertation has been accepted and approved in partial fulfillment of the requirements for the Doctor of Philosophy degree in the Department of Geography by:

Amy K. Lobben	Chair
Alexander B. Murphy	Member
Patrick Bartlein	Member
Stephen F. Fickas	Outside Member

and

Kimberly Andrews Espy	Vice President for Research & Innovation/ Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

Degree awarded March 2013

DISSERTATION ABSTRACT

Maureen Ann Kelley

Doctor of Philosophy

Department of Geography

March 2013

Title: Route Descriptions Using Maps, Photomaps, and Imagery: An Experimental Analysis

Previous route description experiments conducted by psychologists show there are differences between males and females in the use of landmarks when describing routes. Previous research has shown that females used landmarks and egocentric forms of turn descriptors more often than males for route descriptions. This method is known as route knowledge in the spatial knowledge literature. Males, conversely, were seen to use fewer landmarks and more cardinal direction descriptions and standard distances when describing routes. Spatial knowledge literature terms this method survey knowledge.
The current experiment tested the hypothesis that sex is not the determinant of landmark usage for route descriptions but different cartographic methods depicting the same locale determine whether landmarks are described. Two quasi-experiments were conducted using different map types. Results of the experiments show that map type, not sex, influences landmark usage for route descriptions.

CURRICULUM VITAE

NAME OF AUTHOR: Maureen Ann Kelley

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:
University of Oregon, Eugene
San José State University, San José, California

DEGREES AWARDED:
Doctor of Philosophy, Geography, 2013, University of Oregon
Master of Arts, Geography, 2001, San José State University
Bachelor of Arts, Geography, 1991, San José State University

AREAS OF SPECIAL INTEREST:
Theoretical Cartography, Geographic Information Science, Behavioral and Spatial Geography, Historical Geography

PROFESSIONAL EXPERIENCE:

Lecturer, Geography Department, San José State University, San José, California, 2008–2013

GIS Consultant, Wildlands, Inc., Oakland, California, 2004

Lecturer, Geography Department, San José State University, San José, California, 2001–2004

Graduate Teaching Assistant, Geography Department, San José State University, San José, California, 1995–2001

Research Assistant, Dr. Richard Ellefsen, San José, California, 1998–2001

Instructor, San José-Evergreen Community College District, San José, California, 1991–1995

Graduate Teaching Assistant, Geography Department, San José State University, San José, 1995–2001

Cartographer, United States Geological Survey, Menlo Park, California, 1992–1994

Cartographic Technician, United States Geological Survey, Menlo Park, California, 1990–1992

GRANTS, AWARDS AND HONORS:

Graduate Teaching Fellowship, Geography, 2005–2006

Fishman-Wilcoxon Scholarship, Geography Department, San José State University, 2001

Superior Performance Award, United States Geological Survey, Menlo Park, California, 1993

ACKNOWLEDGEMENTS

I would like to thank Professor Amy Lobben for her patience and thought-provoking questions through out my graduate career at the University of Oregon. Also, Professor Patrick Bartlein who always asked the difficult and insightful questions. I would also like to thank Drs. Sean Laraway and Susan Snyserski for their assistance in the design and research protocols at San José State University, and their valuable time and input. I would also like to thank my mother Kathleen and brother Daniel, without their financial assistance I would never have made it this far. Finally, I would like to acknowledge my daughter Ann Marie; who has sacrificed too much in order for her mother to follow her dreams.

To my grandmother Henrietta Katherine and my daughter Ann Marie Elizabeth.

TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION 1

II. LITERATURE REVIEW 4

2.1. Map Design 5

2.2. Map Definition 10

2.3. Map Taxonomy 13

2.4. Environmental Descriptors 17

2.4.1. Landmark Descriptors 17

2.4.2. Distance Estimators 19

2.4.3. Direction Descriptors 19

2.4.4. Spatial Knowledge Acquisition 20

2.4.5. Sex Differences 22

III. METHODOLOGY 23

3.1. Overview 23

3.1.1. Test Instrument Design 23

3.1.2. Test Questionnaire Design 32

3.2. Experiment 1 35

3.2.1. Procedure 35

Chapter Page

3.2.2. Data Coding 36

3.2.3. Identifying Threats to Validity 36

3.3. Experiment 2 37

3.3.1. Test Stimuli Redesign 38

3.3.2. Test Protocol Instructions 39

3.3.3. Demographic Questionnaire Redesign 39

3.3.4. Test Administration 40

3.3.5. Data Transcription 41

IV. RESULTS & DISCUSSION 54

4.1. Experiment 1 Results 54

4.1.1. Demographic Response Results 54

4.1.2. Likert-Scale Analysis 55

4.1.3. Dichotomous Opinion Questions 60

4.1.4. Landmark Usage Statistical Analysis 60

4.1.5. Spatial Information Statistical Analysis 67

4.2. Experiment 1 Discussion 72

4.2.1. Test Administration 72

4.2.2. Demographic Questionnaire Design 75

4.2.3. Likert-Scale Question Design 76

4.2.4. Test Graphic Design 78

4.2.5. Statistical Analysis Design 79

4.3. Experiment 2 Results 81

4.3.1. Demographic Questionnaire Results 81

Chapter Page

4.3.2. Likert-Scale Statistical Analysis 83

4.3.3. Landmark Usage Statistical Analysis 89

4.3.4. Spatial Knowledge Statistical Analysis 94

4.3.5. Confidence Statistical Analysis 104

4.4. Experiment 2 Discussion 110

4.4.1. Test Instrument Redesign 110

4.4.2. Test Administration 111

4.4.3. Calculating an Experience Score 112

4.4.4. Likert-Scale Statistical Analysis Design 113

4.5. General Discussion 113

4.5.1. Research Question 1 114

4.5.2. Research Question 2 117

4.5.3. Research Design 118

4.5.4. Recommendations for Future Study 119

V. CONCLUSION 124

REFERENCES CITED 126

LIST OF FIGURES

Figure Page

2.1 Test map used in Taylor & Tversky (1992) experiments 6

2.2 Map used in Dabbs, Jr., et al. (1998) experiment 7

2.3 Map used in Blades & Medlicott (1992) experiment 9

2.4 Map taxonomy vizualization cube 15

2.5 Map taxonomy visualization in the *x*-*y* plane 16

3.1 Aerial image of downtown Washington, DC used for image manipulation . . 24

3.2 Manipulated satellite image of downtown Washington, DC 27

3.3 Test graphic number 1 (Image) 28

3.4 Test graphic number 2 (Overlay) 30

3.5 Test graphic number 3 (Map) 31

3.6 Experiment 1 Page 1 protocol. 44

3.7 Experiment 1 Page 1 questionnaire. 45

3.8 Experiment 1 Page 2 questionnaire. 46

3.9 Experiment 1 Page 3 questionnaire. 47

3.10 Test graphic number 1 for Experiment 2 (Image) 48

3.11 Test graphic number 2 for Experiment 2 (Image Overlay without Labels) . . . 49

3.12 Test graphic number 4 for Experiment 2 (Map) 50

3.13 Test graphic number 3 for Experiment 2 (Map Overlay with Labels) 51

3.14 Experiment 2 protocol. 52

3.15 Experiment 2 questionnaire. 53

4.1 Response percentages on whether particants preferred another test graphic based on map group 61

Figure Page

4.2 Experiment 1 mean landmark usage per test graphic type grouped by sex . . . 63

4.3 Experiment 1 landmark descriptions results for each test graphic type 64

4.4 Experiment 1 landmark usage showing means and ranges 66

4.5 Experiment 1 distance usage showing means and ranges 68

4.6 Experiment 1 left/right turns counts by sex showing means and ranges 69

4.7 Experiment 1 cardinal direction turn counts showing means and ranges . . . 70

4.8 Experiment 1 non-standard linear distance counts by sex showing means and ranges 71

4.9 Experiment 1 frequency counts for spatial knowledge type grouped by sex . . 73

4.10 Experiment 2 mean landmark usage grouped by sex 91

4.11 Experiment 2 landmark descriptions results for each test graphic type 92

4.12 Experiment 2 mean landmark usage analytic comparisons showing means and ranges 95

4.13 Experiment 2 landmark score based on sex comparing the sexes based on the two Likert-scale questions 96

4.14 Experiment 2 standard distance usage based on sex 98

4.15 Experiment 2 cardinal direction turn usage based on sex 99

4.16 Experiment 2 left/right turn usage based on sex 100

4.17 Experiment 2 non-standard distance usage based on sex 101

4.18 Experiment 2 spatial knowledge type grouped by sex 103

4.19 Experiment 2 distance and direction errors committed based on map type grouped by sex 105

4.20 Experiment 2 total distance and direction errors committed based on sex showing means and ranges 106

4.21 Experiment 2 confidence score based on Likert-scale confidence questions . . 108

4.22 Experiment 2 confidence using current test graphic score (Q14) 109

LIST OF TABLES

Table Page

4.1 Experiment 1 Occupation Responses 55

4.2 Experiment 1 University of Oregon Major Responses 56

4.3 Experiment 1 Occupation Response Matrix 57

4.4 Experiment 1 Recreation Response Matrix 57

4.5 Experiment 1 Inter-item Correlation Scores for Likert-scale Questions 58

4.6 Experiment 1 Factor Loadings for Exploratory Factor Analysis with Varimax Rotation of Likert-scale Questions 59

4.7 Experiment 2 San José State University Major Responses 84

4.8 Experiment 2 Inter-item Correlation Scores for the Likert-scale Questions . . 87

4.9 Experiment 2 Factor Loadings for Exploratory Factor Analysis with Varimax Rotation of Likert-scale Questions 88

4.10 Experiment 2 Sex by Map Type Cell Counts 90

CHAPTER I

INTRODUCTION

Giving directions to another person, whether verbal or written, is one of the most basic forms of spatial communication. While basic, the methods people use to communicate directions vary and include: sketch maps, verbal directions, or written directions. While the communication methods may vary, they all contain environmental objects. A person's direction-giving strategy may be influenced by individual characteristics such as expertise, sex, age, and spatial abilities. Research in cognitive psychology and behavioral geography has revealed sex differences in route descriptions. In general, females tend to give directions in reference to stationary objects in the environment and left-right turns, whereas males tend to give directions using cardinal directions and distances (Dabbs, Jr., Lee, Strong, and Milun, 1998; Galea and Kimura, 1993; Lawton, 1994, 2001; MacFadden, Elias, and Saucier, 2003; Ward, Newcombe, and Overton, 1986).

Much of the previous research on route descriptions, relied on highly schematized geometric maps (Blades and Medlicott, 1992; Bosco, Longoni, and Vecchi, 2004; Gale, Golledge, Pellegrino, and Doherty, 1990; Lovelace, Hegarty, and Montello, 1999; Taylor and Tversky, 1992), or planimetric maps that use iconographic symbolization for landmarks (Dabbs, Jr. et al., 1998; Galea and Kimura, 1993; MacFadden et al., 2003). Although Davies (2002) used a digital version of a UK Ordnance Survey map testing subjects' concept of a map, the majority of test maps are generalized maps as described above. Yet a review of the literature has not uncovered previous research using maps conforming to conventional cartographic production methods, or different types of maps, as test instruments.

These prior studies used line or sketch maps with no topographic or photographic base information. Cartographers know that all maps are not designed and created equally. What the general public envisions as a map, a cartographer envisions many different products with varying ways of depicting the landscape depending on the purpose and target audience.

Maps designed for street navigation range from larger scales for city districts, or neighborhoods, to smaller scales for cities. Sophisticated Internet mapping services, such as Google Maps, allow users the choice for viewing a line map, aerial image, or composite satellite image with labels. Casual map users are exposed to these products that were once available only to mapping professionals. Yet, even though ubiquitous, cartographic professionals and researchers have not yet investigated the influence these different map types have on route-description strategies. Instead, what is provided by these Internet mapping services is a one-size-fits-all approach.

This dissertation addresses the gap between what is currently prescribed for route descriptions based on one map type and what may be preferred by individuals given different map types. This research focuses three general map types: street map, aerial photographic map, and aerial image. The following research questions are investigated:

1. Does map type mitigate route-description strategy?

2. Does sex confound confidence and accuracy in describing routes?

The remaining chapters of this dissertation will review relevant literature on map design, map definition, environmental descriptors, and sex and developmental differences in spatial knowledge acquisition (Chapter II). Chapter III will detail the research methodology and design evolution for two human subjects experiments. Chapter IV will present the results and discuss the significance of the experiments to cartographic design and Geographic Information System (GIS) network algorithms. The final chapter will sum up the research work and conclude with final thoughts.

CHAPTER II

LITERATURE REVIEW

Many social science researchers, such as environmental psychologists, developmental psychologists, and behavioral geographers, have performed experiments regarding human-environment interactions related to route descriptions. These researchers have investigated how people of all ages acquire spatial knowledge, navigate or find their way in the environment, and describe routes. Previous research (Dabbs, Jr. et al., 1998; Galea and Kimura, 1993; Lawton, 1994; Ward et al., 1986) argues route descriptions are sex based. That is, males and females describe routes differently. These researchers designed test protocols using sketch or schematized maps, rather than cartographic products. Yet few to none of the previous research investigated whether different map types influence route descriptions. The current research project addresses whether map type, not sex, influences landmark usage in route descriptions. A review of the literature identified four areas related to the current study: map design and definition, environmental descriptors, spatial knowledge acquisition, and sex differences in spatial knowledge and behavior.

The following sections will address other researchers' maps for route description experiments followed by a review of pertinent literature on the definition of what is a map. Following the previous discussion is a review of literature in environmental psychology and behavioral geography related to describing spatial objects and route descriptions. Because this paper addresses spatial objects and their descriptions, the next section will address theories related to spatial knowledge acquisition from the developmental psychology and behavioral geography fields. Finally, a review of sex differences as it relates to spatial knowledge acquisition and behavior will be addressed.

2.1. Map Design

Previous research (Blades and Medlicott, 1992; Dabbs, Jr. et al., 1998; Galea and Kimura, 1993; Golledge, Ruggles, Pellegrino, and Gale, 1993; MacFadden et al., 2003; O'Laughlin and Brubaker, 1998; Taylor and Tversky, 1992; Ward et al., 1986) for route description relied on fictionalized planimetric maps similar to graphics. The researchers designed the maps using various methods to depict environmental objects in the landscape such as iconographic symbolization for landmarks (Dabbs, Jr. et al., 1998; Galea and Kimura, 1993; MacFadden et al., 2003; Taylor and Tversky, 1992), schematic maps (Blades and Medlicott, 1992; Golledge et al., 1993; Ward et al., 1986), or floor plans (O'Laughlin and Brubaker, 1998). The following paragraphs are brief descriptions of the test maps designed and used in some of the route description studies that were referenced during the duration of search of sources.

Taylor and Tversky (1992) designed one of their test maps using the Macintosh Paint (MacPaint) program depicting a planimetric "Map of town" (p. 266) showing pseudo-isometric mountains in the background where some streets are labelled left to right for east-west oriented streets and cascading top-down for north-south oriented streets. Buildings are featured as simplified rectilinear features and labelled accordingly. A coarsely textured polygon feature depicting a river with the appropriate label is oriented north-south and is labelled outside the feature. The test map includes a very large, very simplified 4-point compass roses without a graphic scale bar (see *Figure 2.1* on page 6).

Taylor and Tversky (1992) conducted multiple experiments testing subjects' abilities to draw maps from memory via survey description, route description, or maps. The survey description was based extrinsic frame of reference such as cardinal directions—north, south, east, west—and distances. The route descriptions were based on egocentric left-right and front-back frame of reference; with the maps showing the

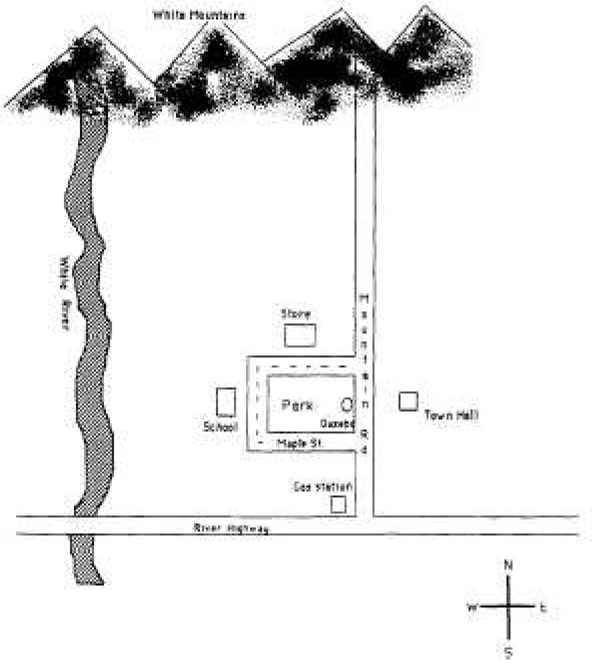


FIGURE 2.1. Second test map used in Taylor & Tversky (1992) route description experiments. The pseudo-isometric mountains are seen at the top. Reprinted by permission from "Spatial mental models derived from survey and route descriptions," by H. A. Taylor and B. Tversky, 1992, *Journal of Memory and Language, 31*, p. 266. Copyright 1992 Elsevier.

extrinsic frame of reference thus facilitating survey descriptions. However, the researchers did not question whether map design would influence the outcome of the experiments.

Another example of an experimental map is by Dabbs, Jr. et al. (1998) for their route description experiment, see *Figure 2.2* on page 7. The researchers use pictographs for large buildings in the environment such as the "Texaco Gas," "McDonalds," "Big Savings," and "Kroger" stores. Depiction of trees are shown as pictographs as well. On the same map larger objects such as the "General Hospital," "Airport," and "Brighten Mall" are depicted as two-dimensional iconographic symbols. All streets are labelled and, for the most part, aligned with the graphic lines. Although the test map graphic includes the standard scale bar, compass rose, and stated scale, their test appears to be similar to

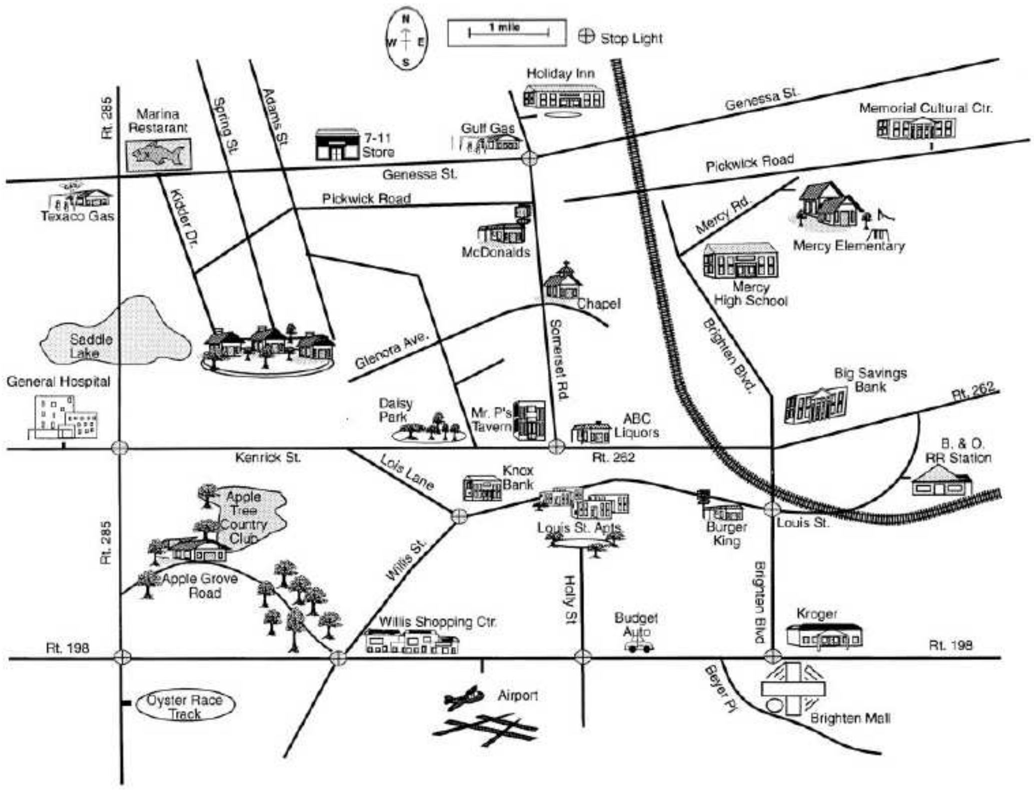


FIGURE 2.2. Map used in Dabbs, Jr., et al. (1998) route description experiment. The iconographic symbols can be seen throughout the map. Most buildings are depicted as pseudo-isometric figures. Reprinted by permission from "Spatial ability, navigation strategy, and geographic knowledge among men and women," by J. M. Dabbs, Jr., E. L. Chang, R. A. Strong, and R. Milun, 1998, *Evolution and Human Behavior, 19*, p. 92. Copyright 1998 Elsevier.

maps designed for less experienced map users given the icongraphic symbols. Dabbs, Jr. et al. (1998) conducted extensive testing to determine sex differences in spatial abilities using various test instruments including the above map. The researchers found significant differences in abilities, navigation strategies, and route descriptions yet never questioned if the map was redesigned, would there be a different outcome.

MacFadden et al. (2003) modified the Dabbs, Jr. et al. (1998) test map described above. The researchers moved and enhanced the landmarks for higher contrast to guarantee the required 5° visual angle in their eye-tracking study. The researchers redesigned the graphic scale bar, north arrow, and “stop light” legend as well. Instead of a simplified 4-point compass rose used in the Dabbs, Jr. et al. (1998) experiment, the 4-point compass rose is elongated and more elaborate. The Dabbs, Jr. et al. (1998) map’s graphic scale was a simplified to a 1 mile rake scale centered in a rectangular box. In comparison, the MacFadden et al. (2003) graphic scale’s distance was set to 2.0km surrounded by a graphic circle. The map elements of scale, north arrow, and “street light” legend were moved to the center left margin from the top center location used in the Dabbs, Jr. et al. (1998) test map in order to minimize test subjects attending the map marginal elements. Although the MacFadden et al. (2003) eye-tracking study did not reveal sex differences in attending to graphic elements on the map, the researchers did not question whether the test graphic could have influenced the results.

Contrast the above to the Blades and Medlicott (1992) test map, *Figure 2.3* on page 9. The researchers designed a map depicting an urban environment using a planimetric view with the intent of being “similar to a conventional road map” (p. 178) with pictographs of landmarks with labels such as “garage,” “library,” and “post office.” In all 16 landmarks were used for the experiment. Because Blades and Medlicott (1992) were studying route descriptions across all ages, the researchers did not want to have the younger children at a disadvantage, thus the streets were unlabelled. The authors chose to highlight the test route in red in an effort to to guarantee high contrast and easy recognition and identification.

An observation of previous literature appears to show a relative lack of attention to map design with the exception of the Blades and Medlicott (1992) experiment. Although this is not intended to be a cartographic critique, perhaps deliberate design decisions were not considered in the instrument design as Robinson and Petchenik (1975) noted that other disciplines “take the concept of a map for granted” (p. 1).

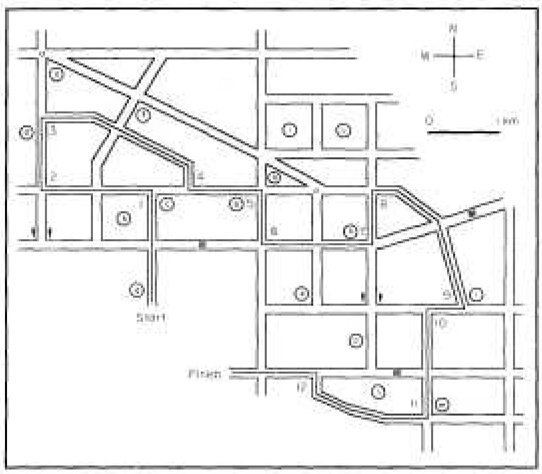


FIGURE 2.3. Map used in Blades & Medlicott (1992) experiment depicting an urban landscape. Point symbols represent landmarks. (Pictographic symbols not used in published work.) Reprinted by permission from, “Developmental differences in the ability to give route directions from a map,” *Journal of Environmental Psychology, 12*, p. 178. Copyright 1992 Academic Press.

In fact a review of the experimental research on route descriptions using test maps appears to bear this out. Discussions regarding whether design choices could influence the outcome of route descriptions did not appear to be taken into consideration. Design considerations on the choice of point and area symbols (iconographic or abstract; two-dimensional or pseudo-three-dimensional), map marginalia design (scale bar style, position, and size; north arrow or compass rose) appear to not be a consideration regarding the outcome of the test results.

A cursory analysis of route the description literature for the last 20 years shows the majority of research has been conducted in psychology (Allen, 1997, 2000; Bigel and Ellard, 2000; Blades and Medlicott, 1992; Bosco et al., 2004; Dabbs, Jr. et al., 1998; Davies, 2002; Galea and Kimura, 1993; Holding and Holding, 1989; Honda and Nihei, 2003; Lawton, 2001; Lovelace et al., 1999; MacFadden et al., 2003; Schneider and Taylor, 1999; Taylor and Tversky, 1992; Tversky and Lee, 1999). More recent research has been conducted in human cognition (Daniel and Denis, 2004; Daniel, Tom, Manghi, and Denis, 2003; Fontaine and Denis, 1999; Michon and Denis, 2001; Tom and Denis, 2004) and computer science (Sorrows and Hirtle, 1999) for on-board vehicle navigation systems and robotics. Geographic researchers such as Golledge et al. (1993) and Gale et al. (1990) appear to be in the minority in regards to conducting research on route descriptions.

If fictionalized maps that appear to be more cartographic than previous investigators' maps, would there be different route description results? Or will the cartographic design of the test instrument have no influence on route descriptions? Is a map just a map? For the purpose of this dissertation would map design—or different map types—influence test participants' describing a route? The following section addresses what is considered a map, and why "taking...a map for granted" is problematic when conducting human subjects research (Robinson and Petchenik, 1975, p. 1).

2.2. Map Definition

Agreement on how to define the ubiquitous construct of "map" can be contentious. Why the debate over a simple word? According to the *Webster's New International Dictionary, 2nd ed.*, a map is ". . . of the surface of the earth, or some part of it, showing the relative size and position . . ." (Neilson, Knott, and Carhart, 1934, p. 1500). The older *mappa* (cf Latin) comes from *mappa mundi* or map of the world, from an older Punic word for napkin or signal cloth (Neilson et al., 1934, p. 1500). These older words bring to mind visual images of ancient maps. Maps of Claudius Ptolemy's mappo mundi, the European Dark Ages world view in the T-in-O maps, the portolon charts of the Mediterranean Sea merchants, to Gerardus Mercator's map for exploring the "New World". A more modern view of a map would be a U. S. Geological Survey topographic map, an Automobile Association of America (AAA) road map, or an Internet map from Google used to get directions from point A to B.

Maps are, arguably, as old as human civilization (Bagro, 1964; Robinson and Petchenik, 1975; Thrower, 2007). However, Wood (2010) counters that maps were not invented prior to the 1500s. What Wood (2010) might not recognize that without the invention of the wood-block printing, the printing press (Bagro, 1964), and the Age of Exploration (Thrower, 2007); we would not have the ubiquity of maps we see today. Maps can be seen as the ephemera of civilization, useful at the time of publication but quickly outdated and thus easily discarded.

The definition of a map can be as general as anything that depicts Earth's surface (Greenhood, 1964; Robinson and Petchenik, 1975; Thompson, 1988). Even a "rough sketch" on a napkin can be defined as a map (Thompson, 1988, p. 15). Other examples are "hospitality cartograms," or sketch maps, you send to your friends showing directions to get to your house (Greenhood, 1964, p. 200). These are examples of generalities and loosely-based definitions, but what about more technical definitions?

Robinson and Petchenik (1975) write that a map is a "graphic representation of the milieu" (p. 16). But what is "the milieu"? Did Robinson and Petchenik need to use a sophisticated French word for environment to give credence to the opinion that anything can be mapped? A map can be defined as a graphic communication device (Kolácný, 1977; Robinson and Petchenik, 1975). However, MacEachren (2004) argues against thinking of maps strictly as communication devices but as one of the many "potential representations" of spatial phenomena that map users can "draw upon" to make spatial decisions (p. 12). Kraak and Ormeling (2010) attempt to define maps using the term "model" as a way to understand the "geospatial relationships" of objects (p. 39). Another view is that a map not only depicts spatial features on Earth, rather a map graphically—or visually—reveals patterns of various phenomena from the spatial locations of scientific research to the graphic depiction of the structure of science (Börner, 2010).

Harley (1989) argues map hold hidden, and arguably, cultural meanings that reveal more about the producers rather than the land depicted. Barkowsky and Freksa (1997) concede many people believe maps "are more real" than the actual environment (p. 349). Thus maps take on a greater authoritative quality that was never intended by cartographic technicians. Wood (2010) even goes so far and questions whether a landscape painting could be a map (p. 23), for surely a landscape painting is a "graphic representation of the milieu" as Robinson and Petchenik (1975) so duly note. However, there is a tacit understanding that maps are depictions of the environment from a high height and not on a person's ground-based perspective.

What is a map? The graphic depiction of present conditions? Do maps represent reality? Or are maps simplified models of features of Earth that have been subjected to aggregation, generalization, and abstraction? A document that takes a snapshot of spatial and temporal dimensions that will be most likely be out of date by publication time? MacEachren (2004) argues maps do not reveal reality but are abstract representations of reality that we build from; we do not reveal reality but create knowledge of reality (p. v). Kitchin and Dodge (2007) argue maps are not "social constructs" or "mirrors of nature" but rather "emerge" from technical and cognitive processes depicting and understanding the environment represented on the graphic (p. 340). Couclelis and Gottsegen (1997) comment that maps are both denotative and connotative, depicting geographic objects and implying the potentialities of said objects based on map users' intent and experience.

Maps can be defined by their technical definition of spatial representations that can be systematically reduced in scale and processed via mathematical transformation and generalization (Kimerling, Buckley, Muehrcke, and Muehrcke, 2009; Robinson, Morrison, Muehrcke, Kimerling, and Guptill, 1995; Thompson, 1988). Maps graphically depict objects on Earth's surface identifying absolute, as well as relative, locations in order to help us depict spatial features Earth's surface that ultimately lead us to understand spatial phenomena. What is most important is a map is solely dependent on scale; for Earth can never be depicted at its true scale.

The definition of a map—after many years of reading scholarly works, talking to colleagues, and my professional development—is an instrument that uses one or more of the five senses to help humans depict spatial phenomena. The vast majority of maps are designed for using visual perception or the sense of sight. Some experimental maps are designed for the blind and visually impaired (Lobben and Lawrence, 2012) using the sense of touch (Horsfall, 1997), or braille maps of USGS topographic quadrangles (Sherman, 1976), or touch and sound known as haptic soundscapes (Lawrence, Martinelli, and Nehmer, 2009). For the purpose of this project, maps designed for visual perception are used as test instruments.

2.3. Map Taxonomy

Perhaps one of the reasons for fully defining the construct of "map" is due to the plethora of different types of maps. A categorical structure for maps can be based on several different criteria, such as medium (paper, plastic, model, digital, mental. . .) and use. Because the foundation of this dissertation lies in map use and the effect of different map types, a detailed categorization of maps based on use provides an organizational structure for this research.

This categorization of maps can be visualized as a cube with the categorization of levels of cartographic manipulation, categorization, and scale on each axis, *Figure 2.4* on page 15. The levels of cartographic manipulation are shown on the *x*-axis where the closer to minimum manipulation are unrectified imagery and aerial photography to rectified imagery. Farther away from the ordinate axis are photomaps, or cartographic overlays of imagery, as the next step of cartographic manipulation. The farthest away from the *y*-axis of cartographic manipulation is the various types of planimetric maps sub-categorized into general purpose and thematic maps. Thematic maps would be considered to be on the spectrum of cartographic manipulation to be the most manipulated; whereas, unrectified imagery or aerial photographs the least manipulated.

The *y*-axis represents levels of categorization where the top-most level depicts the three general categories of imagery, photomap, and maps. Subsequent levels of categorization are map types under the general heading of general purpose, such as planimetric, topographic, or chart; versus thematic maps based on statistical manipulation, either quantitative or qualitative data. Thematic maps can be sub-categorized based on manipulation of the graphic primitives such as points, lines, and polygons. The closer a map category approaches the abscissa, or *x*-axis, the more specialized a map's purpose, see *Figure 2.5* on page 16.

The *z*-axis represents scale as seen in *Figure 2.4* on page 15. The closer maps are categorized to the *x*-*y* plane, the larger scale a map depicting a relatively small area. Conversely, the farther away from the *x*-*y* plane, the smaller scale a map and larger the area. Conceivably many map scales are not fixed but can vary depending on the purpose and target audience. As evidenced from above, the construct of "map" will depend on the three criteria. All maps, arguably, are dependent on scale where the process of selection, generalization, aggregation, and symbolization are intrinsic to the production of a map. Cartographic manipulation can range from raw image to thematic map, categorization based on the purpose of the map, and lastly, scale based on the area of interest. These three combine to determine the level of finished product, purpose, and scale. Thus the

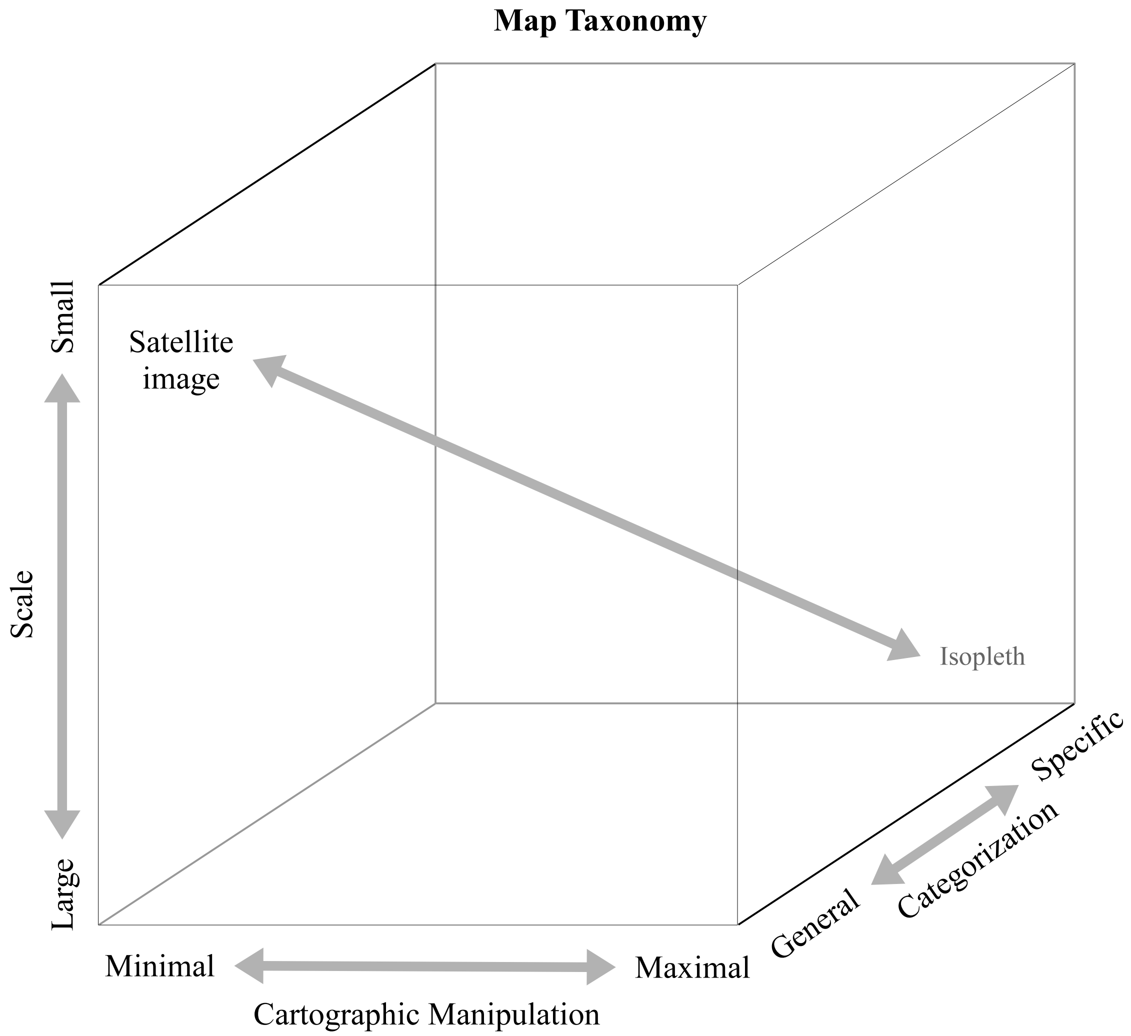


FIGURE 2.4. Map taxonomy visualization cube where the *x*-axis represents cartographic manipulation levels, the *y*-axis represents cartographic categories, and the *z*-axis represents scale.

Map Taxonomy

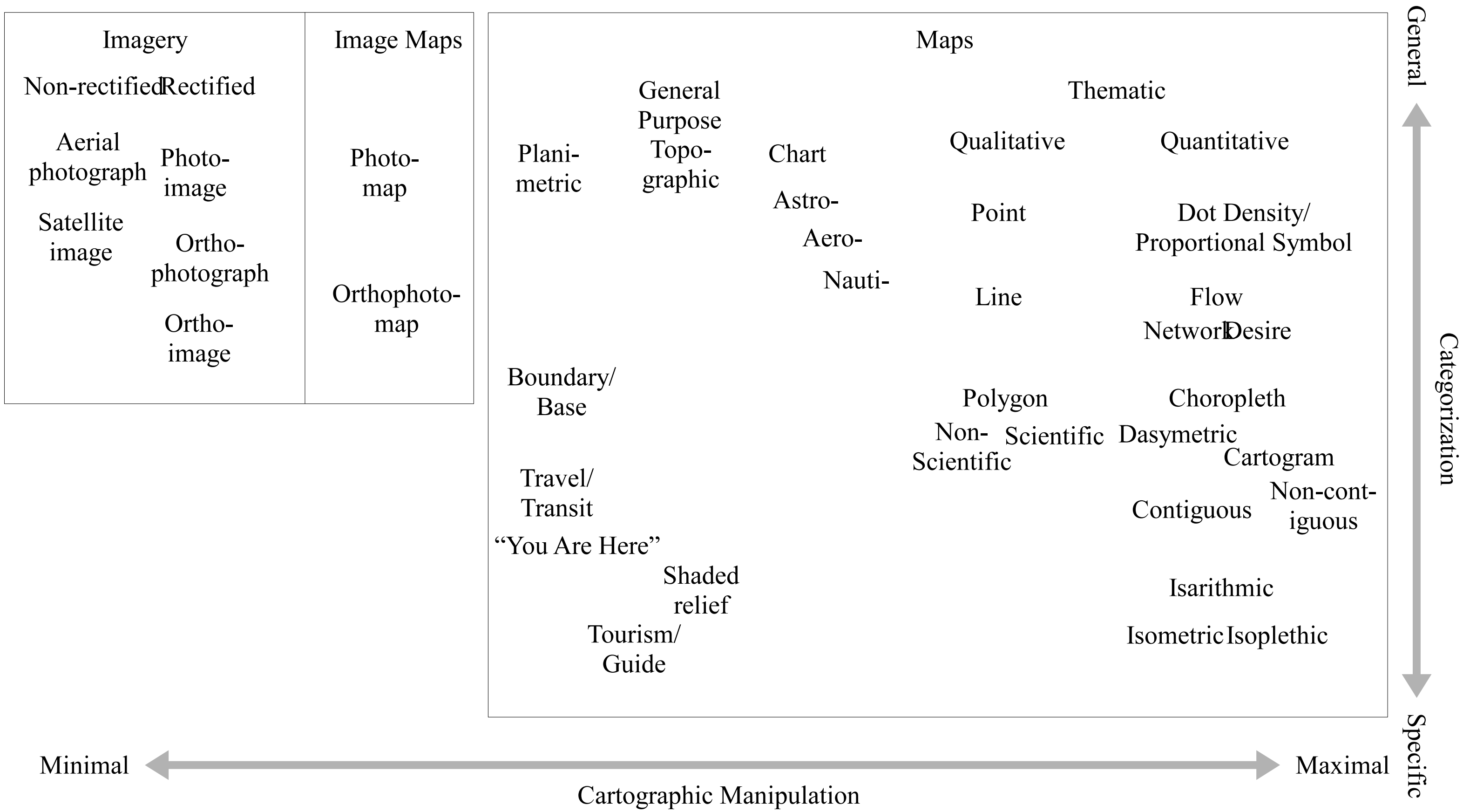


FIGURE 2.5. Map taxonomy visualization *x-y* plane showing the three general cartographic manipulation categories on the *x* dimension, and the cartographic purpose on the *y* dimension.

construct of “map” is very general given the types of maps produced, the intended purpose, and the output scale. The previous section addressed the definition of what is considered a map. The following section addresses the various academic disciplines that investigate how humans describe features in the environment.

2.4. Environmental Descriptors

Allen (1997) identified criteria of route descriptions that are communicative in nature. When people engage in the activity of navigating from one location to another they either follow a prescribed route or they determine their own. When asked to provide directions that would allow another person to follow the same route, those directions are littered with communicative route descriptions. These descriptions may be categorized based on information such as locomotion verbs (Allen, 1997, 2000), descriptions of environmental features (Denis, Pazzaglia, Cornoldi, and Bertolo, 1999; Lynch, 1960; Michon and Denis, 2001; Ward et al., 1986), and delimiters for distance and directions estimators (Allen, 1997, 2000; Berendt and Jansen-Osmann, 1997; Denis et al., 1999; Montello, 1997; Ward et al., 1986).

2.4.1. Landmark Descriptors

The simplest environmental descriptor, landmark, is defined as a large or small stationary object that can be used for guidance along a path (Allen, 1997; Ward et al., 1986). Many researchers identify landmarks as variable-sized stationary objects in the environment which are used for guidance along pathways (Allen, 1997, 2000; Denis et al., 1999; Lynch, 1960; Michon and Denis, 2001). Landmarks have been classified as two general types: a two-dimensional feature such as a street or path, and a three-dimensional object where buildings are the dominant feature (Denis et al., 1999; Michon and Denis, 2001). Maps used in psychological research conducted by Galea and Kimura (1993) depicted landmarks such as apartment buildings, shops, and ponds (p. 55). Ward et al. (1986) identified landmark as small as stoplights, intersections of streets, even road names, or large stationary objects such as building or other features—i.e. zoo or cemetery (p. 203).

Why landmarks are used in describing routes has been researched as well and are used as points of reference tieing the objects to the landscape. Denis et al. (1999) notes that "landmarks are cues for orientation" within the environment (p. 148). Allen (1997) note that landmarks are used as "...subgoals that keep the traveler connected..." from the origin to the destination (p. 366). Daniel et al. (2003) and Daniel and Denis (2004) identify three classes of landmark descriptors such as an action with reference to (turn right at the ...), introduction to (you will see a ...), or description of a landmark (the building is ...) when describing a route.

Couclelis, Golledge, Gale, and Tobler (1987) hypothesized that landmarks at or near the start and or end of a route are important for a person to orient themselves in the environment. The anchor-point theory, as Couclelis et al. (1987) termed the concept, allows for these important starting and ending landmarks to be anchored to the landscape and become the foundation for a frame of reference. Blades and Medlicott (1992) and Daniel et al. (2003) observed that landmarks are used at critical turn junctions. Blades and Medlicott (1992) commented adult participants tend to use critical road junctions, such as a T-intersection, as a landmark. What the above show is that people use landmarks as references for directionality.

Whether landmarks are strictly nodal structures or independent of a route environment is not settled in the literature. In fact, Golledge et al. (1993, p. 294) recognized that "the importance of landmarks as components of routes is sometimes ignored." For the purposes of this experiment, landmarks are defined as large three dimensional objects in the landscape similar to Lynch (1960), Galea and Kimura (1993), and the second definition of Denis et al. (1999). The landmarks used in this dissertation will have landmarks as structures associated near critical junctions along paths and three landmarks along a path.

2.4.2. Distance Estimators

Distance estimators can be based on objective or subjective criteria (Berendt and Jansen-Osmann, 1997; Montello, 1997). Distances can be perceived as concrete concepts such as linear distances across the surface of Earth or perceived distances in terms of cost of effort (Montello, 1997). The objective criteria are based on ground distances as they relate to navigation or map reading. The units of measurements employed are usually standard distance measurements: feet, miles, meters, or kilometers depending on the convention of the culture. Subjective criteria for distance estimation have been hypothesized as a function of a person's cognitive map (Thompson, 1963). Objective distances, such as meters and feet, and subjective distances, such as blocks and intersections, will be investigated in this dissertation.

2.4.3. Direction Descriptors

Turn types are based on a person's viewpoint. The egocentric turn types are referenced as if a person is facing forward and views the left-hand or right-hand sides. The allocentric, or synoptic view, is theorized as a physical map in a person's mind. These turn types are based on a person's inherent understanding of cardinal directions: North, South, East, and West. Both turn types will be investigated in this dissertation.

2.4.4. Spatial Knowledge Acquisition

Spatial knowledge is the concept of how a biological entity, such as a human, understands and interacts with the environment in order to get from one place to another. Researchers categorize human spatial knowledge in three general stages: landmark, route, and survey knowledge. Landmark knowledge, or the ability to know where important objects in space are located, is considered the first stage of spatial knowledge acquisition (Golledge et al., 1993; Siegel and White, 1975).

Route knowledge, or procedural knowledge, is the recognition and identification of objects along learned or experienced paths (Golledge and Stimson, 1997). Survey knowledge is based on experiential methods of travel where the individual builds up knowledge of the environment by following learned paths to gain a greater understanding of an area (Golledge et al., 1993; Golledge and Stimson, 1997).

Siegel and White (1975) identified a developmental model of spatial knowledge acquisition based on the works of Piaget and Inhelder (1967). Siegel and White (1975) theorized that information is acquired by initially recognizing and remembering landmarks, then the landmarks are connected by routes, and information is then conceptualized as distances and directions between routes and landmarks. Children's developmental stages go through the initial landmark phase, then the egocentric procedural route phase, and eventually to the synoptic and metric survey knowledge phase by the beginning of adolescence.

Golledge and Spector (1978) suggested a hierarchical ordering of features in the landscape based on the importance of a person's mode of travel in the environment. Features such as home, school, or office can be used as anchors or starting or ending points. Thus these become the anchors for personal navigation. The anchor point theory, similar to a topological data structure, uses nodes as the linkages in networks to navigate

(Couclelis et al., 1987). Golledge and Spector (1978) added to the theories of Siegel and White (1975) that landmarks are anchored in the landscape. These frames of references, or starting points, are used to acquire new knowledge about the environment and are generated from these anchor points.

The concept as described above is hierarchical in nature starting with the landmarks (anchor points), connecting the routes, and then finally the areas. Golledge et al. (1993) theorize these are cognitive maps that are used as an internalized geographic information system (GIS) that conforms to topological data structures. That is, nodes are the landmarks or anchor points, lines are the routes connecting the nodes, and polygons have hierarchical structures that conform to topological rules.

Montello (1998) enhanced the above concept for the hierarchical acquisition of spatial knowledge by suggesting that metric knowledge can actually begin immediately, citing psychological research studies in distance estimation (Evans and Pezdek, 1980; Levine, Janovic, and Palij, 1982; Thorndyke and Hayes-Roth, 1982). Montello (1998) identified elements of spatial knowledge, as outlined above, but argued that metric knowledge exists at the outset and non-metric knowledge is not necessarily a precursor to metric knowledge. Montello (1998) also argued that metric knowledge can be stored as a function of a linguistic sense of space and not just in topological terms. Thus, humans begin to use distance and direction estimations early in the process of spatial knowledge acquisition. Whether a person's knowledge of distances and directions are perfect has been debated as well (Couclelis et al., 1987). What researchers have noticed is a general trend of sex-based differences between the two spatial knowledge categories.

2.4.5. Sex Differences

Numerous psychology researchers (Dabbs, Jr. et al., 1998; Galea and Kimura, 1993; Holding and Holding, 1989; Lawton, 1994; Ward et al., 1986) investigated sex differences in spatial abilities, wayfinding behavior, and route descriptions. These researchers reported that males described more distance estimations and cardinal directions, whereas females used more landmarks and left/right turns. However, Michon and Denis (2001) noted that females used more two-dimensional landmarks than males but there was no difference between the sexes when referencing three-dimensional landmarks.

Previous research (Galea and Kimura, 1993) on sex differences in route learning from memory showed females remembered more landmarks than males. The same researchers reported males recalled distances more than females. Holding and Holding (1989) noted from their experiments that males were more accurate in angular and distance estimations than females. Lawton (1994) noted differences between the sexes' route-finding strategies. Males tend to use "orientation strategies," relying on distances, directions, and sun position for wayfinding. Whereas females tend to use "route strategies" relying on left/right turn types and landmarks for getting around the environment.

Developmental psychologists investigated adolescents and children on sex-related differences on direction-giving from memory (Choi and Silverman, 2003; Miller and Santori, 1986). Both groups concluded sex-related differences were present; females preferred landmarks and males favored distances and directions. Yet geographers Kitchin (1996) and Gilmartin and Patton (1984) found no differences between the sexes on mapreading related tasks.

CHAPTER III

METHODOLOGY

3.1. Overview

Two experiments were conducted to test the main hypothesis that map type influences landmark usage in route descriptions. The first experiment was exploratory in nature at the University of Oregon in a graduate student seminar class headed by Dr. Amy Lobben in 2006. The second experiment was conducted at San José State University in 2007 and 2008.

3.1.1. Test Instrument Design

The University of Oregon (UO) research group used a black and white aerial photographic image as the base map to alleviate color blindness as a potential confounding variable. An IKONOS satellite image (Satellite Imaging Corporation, Magnolia, TX) was used for the base image. The image was manipulated to include large and easily recognizable landmarks. The Washington, DC area was selected because of building height restrictions, and relatively uniform gridded street patterns with radiating streets from traffic circles (Cameron, 1979). The original geographic location is approximately 0.5 miles north-northwest of the U. S. Capitol in downtown Washington, DC (See *Figure 3.1* on page 24). Several changes, described below, were made to the original image in order to counter any familiarity that a research participant may have with the city and the raw image. The image was rotated 90°counter-clockwise to make sure no person could recognize the city from the original orientation.

FIGURE 3.1. Aerial image of downtown Washington, DC showing the area used for image manipulation. The above view is of the southeast quarter of the 1993 1-meter ground resolution Washington West, DC–VA digital orthophotoquad (Source: National Seamless Data Distribution Center, U. S. Geological Survey).

The maps were produced on standard 8.5″ by 11″ 20 lb. bond paper. Each image was 8″ wide by 8.5″ tall. The map scale was set at 1:6,250. The bottom 1.5″ of the test maps showed a graphic of the points A to B, a 3.2cm (1.6″) rake scale depicting 2–100 meter intervals. A simplified north arrow was designed using an 18 pt Arial capital "N" centered 2/16″ above a 0.02″ black 0.4″ line using a standard arrowhead (0.09″ by 0.12″).

Many large buildings were retained from the original image. In the southeast portion of the image is a track field called *School Track*, corresponding to Dunbar Senior High School track field. The *School Track* established an anchor landmark (Couclelis et al., 1987) at the beginning of the proposed route. The large white building in the northwest section of the image is the Verizon Center. To the southwest of the aforementioned building is the National Building Museum near Judiciary Square. This building was identified on the test map graphic as *Hospital*. A white cross was added to the image and map overlay to determine if participants would recognize the cross on the building and identify that building as a hospital. Four additional landmarks were added to the test image.

The four landmarks were deliberately placed to determine if these landmarks would be mentioned in the route descriptions. Two features along the test route path were a building complex called *Courthouse* and a baseball field called *Baseball Field*. The *Courthouse* feature obscured U. S. Interstate 395 (I–395) between K St., NW and New York Ave., NW. This building is actually the U. S. Department of the Interior building clipped from the original image, moved to its current location, and rotated 180°. The baseball field was added because of its familiar shape for Americans, and the selection of the location was to try to place it as near to the track field as possible to see if this feature would be mentioned as an along-the-path landmark. The baseball field is actually of a larger scale than the test map. At scale the baselines are 488 ft in length, rather than the regulation 90 ft.

A park, called *City Lake Park*, was placed at a juncture in the route that conveniently masked the large Washington Convention Center. *City Lake Park* is actually Constitution Gardens Lake clipped from the original image and rotated 180°from its true orientation. At the end of the route, another landmark was included called *Forest Park*. The dense woodland for the park was clipped from Roosevelt Island and placed in its current location. This feature was added to mask I–395. A total of seven buildings and features were identified as landmarks along the test route path. These landmarks were in order: *School Track*, *Courthouse*, *Baseball Field*, *City Lake Park*, *Arts Center*, *Hospital*, and *Forest Park*. Refer to *Figure 3.2* on page 27 to see the all landmarks.

Three test maps were produced for the first experiment. The first was a raw image with no internal text labels. This graphic was determined to most resemble an air photo. An intermediate test graphic, overlay map, had streets identified and labeled in white over the base image, *Figure 3.3* on page 28. Streets were labeled following the American convention of cities having their street naming system with numbers and letters (Greenhood, 1964). North-south trending streets were numbered, and east-west streets were lettered. The north-south trending streets were numbered increasing from west to east. East-west trending streets were labeled with letters south to north. Radial streets were simply labeled as Broad St., Cross St, and Thru St. These streets correspond to New York Ave. NW, New Jersey Ave. NW, and Massachusetts Ave. NW in Washington, DC, respectively. Because the base image was rotated 90°, and no Washington, DC streets names were used in the project, the test maps' streets would appear to be from a generic American city. See *Figure 3.4* on page 30 to see test graphic 2 (map overlay) depicting the street grid pattern and street labels.

FIGURE 3.2. Manipulated IKONOS satellite image of downtown Washington, DC. The *School Track* can be seen in the lower right of the image. The the *Courthouse* can be seen in the middle right section where the *Baseball Field* is immediately northeast of the building. The *City Lake Park* is in the upper right corner. The *Arts Center* is in the upper left. The *Hospital* is south the the *Arts Center* with a white cross on top of the building. *Forest Park* can be seen in the lower right of the image.

FIGURE 3.3. Test graphic number 1 (Image) depicting basic layout with route path from point A to B. Notice the white cross center left of the photograph depicting the hospital.

The third test graphic was designed to represent a typical large-scale city map. The graphic simulated a planimetric map of the same area. The base color was set at 50% gray to represent the average tonal quality of the image. All landmark footprints were digitized using 30% gray fill. The tonal quality of the base and landmark layers were visually determined to be of sufficient contrast. Text labels for streets and landmarks were placed on the map conforming to cartographic conventions, *Figure 3.5* on page 31.

All text labels for the landmarks were white 18 pt Arial stacked (two lines centered over another) and centered over the feature. All street lines and labels were depicted in white to maximize contrast between the background image and the foreground map overlays. The test graphic streets were digitized over preexisting ones as 2 pt (.028″) wide lines. All street labels were Arial 10 pt bold with a black mask to maximize contrast.

The test path traversed the majority of the map starting in the lower right (southeast corner) and ending at the lower left (southwest corner). There were seven route segments, including a short north-south segment in the upper center of the map to maximize the number of routes corresponding to the number of landmarks identified along the test route. All test graphics used the same path. The map overlay and map test graphics contained the same street labels.

In all, there would be at least one landmark at turn points along the test route. The route path was a thick 6 pt (.083″) white line with a 2 pt black and white dashed line. The black and white dashed line's thickness and texture (0.11″ dash and 0.05″ gap) was visually determined to be sufficient for test subjects to discriminate the route path from the streets. The map overlay and map test graphics were designed using normally agreed upon cartographic conventions and procedures. All cartographic decisions were discussed and agreed upon prior to making the test graphics.

FIGURE 3.4. Test graphic number 2 (Overlay) depicting basic layout with route path from point A to B. This map shows streets mapped and labeled as white overlays.

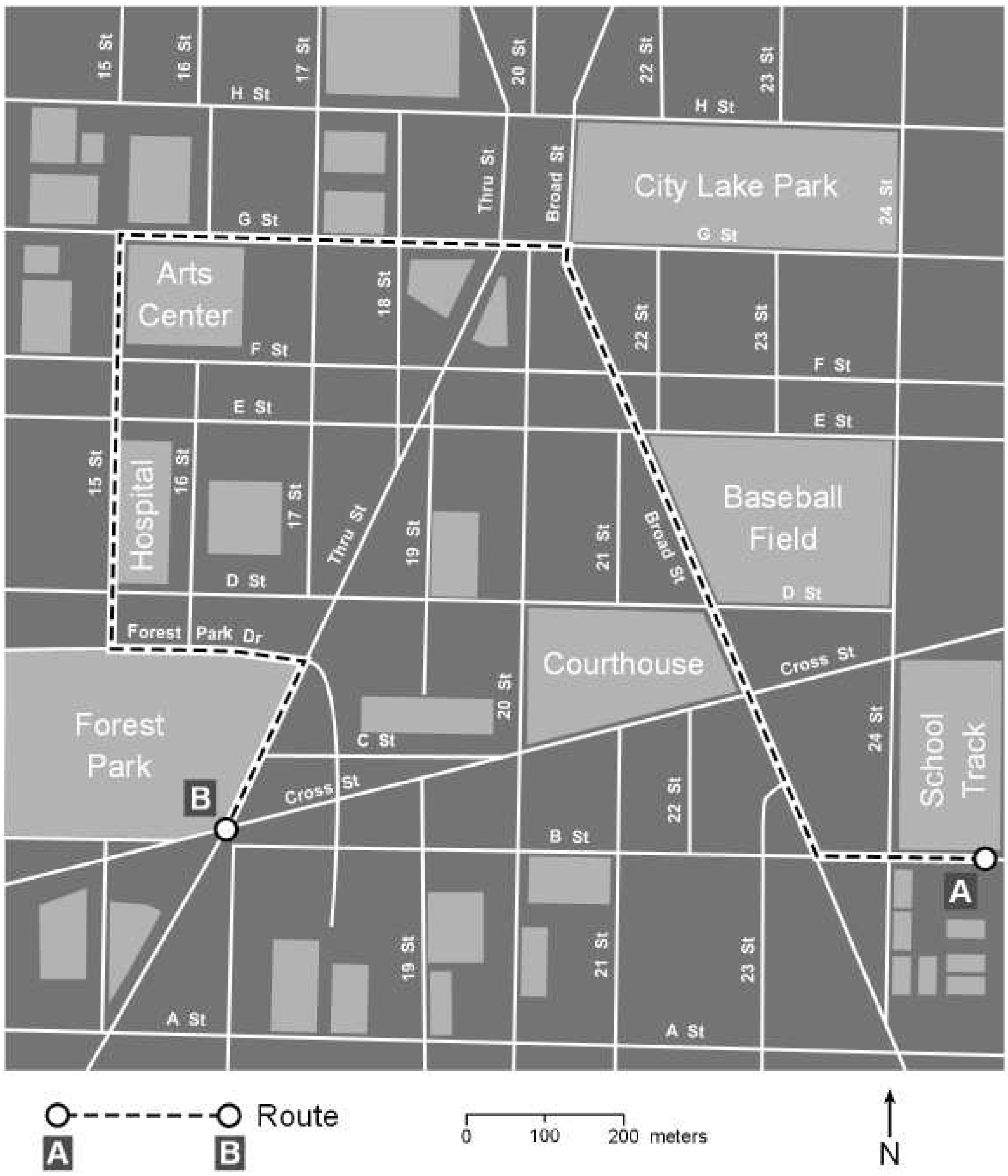


FIGURE 3.5. Test graphic number 3 (Map) depicting basic layout with route path from point A to B. This map has no image background, streets are displayed and labeled with test landmarks labeled.

The UO research group conducted an exploratory experiment during the Spring 2006 quarter. The test stimuli were the graphics described above. The demographic questionnaire was designed as exploratory in nature. Test participants were selected from Geography department classes.

3.1.1.1. Test Protocol Design

The test protocol was designed to be a pen and paper test. Participants were prompted to write down on the same sheet of paper with the following instructions:

> Please use the following space below to describe how you would travel along the highlighted route starting at point A and traveling to the final destination at point B. Write the description as if you are *giving directions to another person* who is unfamiliar with the route.

The prompt was at the top of an 8.5″ by 11″ sheet of paper that was lined for the participants' convenience, see *Figure 3.6* on page 44. After each participant finished their route description task, they were prompted to answer questions regarding their opinion on the test graphic and demographic data about themselves.

3.1.2. Test Questionnaire Design

The first section of the questionnaire asked opinions on map use, navigation confidence, and current map confidence using forced choice Likert-scale questions. Each Likert-scale question had its own five-step scale. Question 1 prompted participants their opinion if the graphic was a map. Questions 2 and 6 prompted participants whether they were confident using the test graphic and whether they were confident navigating with a map, respectively. Question 3 prompted participants whether they would prefer the current test graphic using the Likert scale questions. Refer to *Figure 3.7* on page 45 to view questions 1 to 7.

Question 4, related to Question 3, was a two-part question. The first part was a forced choice binary question (yes/no) that asked participants if they preferred another graphic to the current one. If the participant answered yes, then an open-ended question asked what type of graphic they would prefer. Question 5 prompted participants their opinion on their ease of use for the current test graphic. Question 7 was a two-part question where the first part prompted users to determine if the test graphic helped them for giving them "a sense of the place." The second part of Question 7 was an open-ended question asking participants how the current graphic can be helpful for giving them "a sense of the place."

The last question, Question 8, was multi-part where the first part was forced choice binary question (yes/no) and asked whether the participants recognized the location *Figure 3.8* on page 46. The second part was open-ended and asked if participants where the location was. The third part was a forced choice four-step question whether participants recognized the location.

The second part of the questionnaire was the demographic section and prompted participants' age, sex, occupation, and major if a University of Oregon student. Included in this questionnaire was a forced choice matrix of current or previous occupations and the number of years the test participant was employed.

The second component of the demographic questionnaire was another forced choice matrix of current or previous recreational activities that test participants would need to use maps. The research group speculated that participants who indicated participating in the above activities would be more familiar with maps and, therefore, would be more accurate and confident with map use. Refer to *Figure 3.8* on page 46 for the demographic, occupation, and recreational activities questions. The last page of the questionnaire was simply a thank you statement for the participants cooperation in the study, *Figure 3.9* on page 47.

3.2. Experiment 1

3.2.1. Procedure

Test map stimuli were randomly assigned in each session. All participants in a testing session were assigned the same map. Participants were verbally informed of their consent to participate, and each were asked to write a description of a predetermined route from a starting position to an ending position using one of the three different map types.

Each participant answered the questionnaire sections after completing the description task. The average amount of time for completing the task was approximately 20 minutes. Students taking the test were given extra credit and were allowed to choose other extra credit activities in lieu of taking the test with the University of Oregon Human Subjects—Institutional Review Board approval.

A total of 113 students from laboratory sections of Geography 323—Biogeography (Pacific 217 lab room) and Geography 311—Maps & Geospatial Concepts (MacKenzie 442) participated in the testing sessions. A total of 10 sessions were conducted. The following is a description of the testing conditions.

The first testing room, Pacific 217, is a meeting/geography graduate student office with tables where approximately 10 to 12 students sit facing one another. Because the first testing room is also a graduate student office, other persons not associated with the sessions were present and conversing with other students within earshot of test participants.

The second testing room is MacKenzie 442, the Social Sciences Instructional Laboratory (SSIL) computer laboratory. There are approximately 34 large computer monitors and students sit in front of the computer terminal forward facing. From the outset the testing conditions between the two rooms were not comparable. This eventually proved to be problematic in subsequent testing sessions. Details of the confounding conditions during testing will be addressed in the discussion section.

3.2.2. Data Coding

Route descriptions were hand-coded using Microsoft Word (Microsoft, Corporation, Redmond, WA) by the UO research group in the Spring 2006 term, and the Microsoft Word documents were subsequently converted to ASCII-encoded files. Participants' route descriptions, were hand-coded and processed using ATLAS.ti version 5 (Scientific Software Development GmbH, Berlin, Germany), was performed by this researcher in the Fall 2007 term to gather data regarding participants' route descriptions in terms of landmark usage, turn types, and distances.

Key words or phrases were identified, coded, and searched using ATLAS.ti's powerful GREP (grab regular expression) function. All instances were identified and quantified. For example, if the researcher was looking for the number of times all participants used the phrase *Track Field* or any variants explicitly defined by the researcher, then GREP would code those phrases as such and count the total. The researcher performed exploratory data analysis to determine if there were any differences between route description methods by the sexes and test graphics.

3.2.3. Identifying Threats to Validity

This researcher identified potential confounding variables, not part of the manipulation of the independent variable (Keppel, W. H. Saufley, and Tokunaga, 1992), that could influence the validity of the results of the first experiment. The goal of validity in experimental design is to "provide arguments against all...alternative explanations"

(Krauth, 2000, p. 33). Threats to statistical conclusion validity were identified and addressed for the second experiment.

Because the first experiment was exploratory in nature, there was no specific statistical analysis procedure in mind when designing the experiment. Associated with no specific statistical analysis procedure was the imprecise method of selecting a sample size. The second experiment addressed this concern by redesigning the experiment as a two (sex) by four factor (map type) between subjects experimental procedure using an analysis of variance (ANOVA) test. Sex and map type were identified as independent variables and landmark usage as the dependent variable.

3.3. Experiment 2

A power analysis was performed following power analysis criteria (Cohen, 1992). A large effect size is anticipated when comparing group means using the ANOVA statistical test. The 0.80 statistical power with an alpha level at 0.01 was established due to multiple null hypothesis tests being planned in the current experiment. Sample sizes of 20 participants per group for the eight groups were deemed sufficient to meet the statistical power criterion. Moreover, consistency in participant numbers per testing session supports a balanced design.

Another potential threat to statistical conclusion validity is the reliability of the independent and dependent variables. However, there were no assumptions that the reliability of the independent variables (sex and map type) and the dependent variable (landmarks) were violated. A major threat to the possibility of random disturbances, i.e. testing conditions, were addressed and the second experiment was designed to be conducted under similar conditions.

Threats to construct validity, in reference to how subjects react to testing conditions, were addressed before the second experiment commenced. Because the first experiment used test participants taking geography classes, this researcher was concerned there was reactivity from the participant pool. A common definition of reactivity is when test subject's behavior changes due to testing conditions. Some of the geography participant pool were known to the researchers, thus there might have been an underlying need on the participants' part to perform what we, the researchers, wanted them to perform. To minimize the possibility of reactivity in the second experiment, an anonymous participant pool was used.

The experiment was slightly redesigned with the intent to minimize the number of questions participants needed to answer and group the questions using the same Likert-scale steps. The demographic questionnaire was redesigned following the principle of reducing the observed relation[s] to other known simple relations which can be tested with experiments (Krauth, 2000, p. 30).

3.3.1. Test Stimuli Redesign

Test graphics were redesigned for Experiment 2. The landmark for the hospital was reconfigured for all maps in the new experiment. Thus the white cross was eliminated. See *Figure 3.10* on page 48 for a view of the image test graphic, and *Figure 3.11* on page 49 for a view of the image overlay without labels test graphic. The relabeled landmark, *City College*, can be seen on the map test graphic, *Figure 3.12* on page 50. A fourth map was designed to determine whether there were differences in map overlay with landmarks labeled in comparison to a map overlay with landmarks not labeled, *Figure 3.13* on page 51. Justification for test graphic redesigns will be addressed in the next chapter.

3.3.2. Test Protocol Instructions

The test protocol's written instructions were not modified for the current experiment. However, the lines for the route descriptions were bulleted with the attempt to prompt participants to write each segment's description on one line. This section of the test protocol was modified due to difficulties of coding the route descriptions from Experiment 1. Thus, it was the intent that future coding of route descriptions would not be as difficult as the first experiment, *Figure 3.14* on page 52.

3.3.3. Demographic Questionnaire Redesign

Items related to occupation and recreational activities were removed for the current experiment due to low response rates in the first experiment. Two new items were introduced in the demographic section. Both prompted an open-ended response regarding the number of classes participants took in high school and college. The intent was to use these questions as proxy variables for experience, the higher the number of classes, the greater the experience in map usage.

Two banks of five Likert-scale questions were developed for Experiment 2. The first bank asked participants whether they usually used maps, got lost in unfamiliar cities, use Internet mapping programs, use landmarks for verbal directions, and use landmarks for written directions. The Likert scales were such that 1 corresponded to "almost never" and 5 corresponded to "very often." This bank of questions was considered to address general map use and landmark usage.

The second bank of five questions asked about confidence with map reading, sense of direction, navigating with maps, Internet mapping applications, and confidence using the current map. The Likert scales were such that 1 corresponded to "not at all" and 5 for "very [often]." The bank of questions was developed similar to the ones developed by

Lawton (1994). The two confidence questions regarding navigating with maps and using the current graphic from Experiment 1 are included in this new questionnaire. Questions about Internet mapping applications were included because the rapid popularity of these applications while testing was underway.

3.3.4. Test Administration

Participants were college students recruited from the SJSU Psychology Department and Communication Studies research pools. Participants were recruited in the Fall 2007 and Spring 2008 semesters. Students taking introductory psychology and research methods courses were allowed to participate for credit in their courses. Students signed up either by emailing the researcher directly or adding their names to the sign up sheets on the Psychology Department Research Subject Pool bulletin board.

Testing sessions were group administered similar to Experiment 1. One of the Psychology Department computer laboratories was used for all testing sessions. The room was configured so each student sits in front of a desktop computer. Each computer is set up such that all students face toward the front of the classroom. The computers sit on wide tables that allow for keyboards to be moved and table surfaces exposed for pen and paper testing. Unlike the first experiment, test stimuli were randomly assigned to each participant.

At the beginning of each session, all participants were handed a test packet, asked to take a seat anywhere in the room, asked to read the instructions for their permission to participate in the experiment, and if they had any questions then please raise their hand for assistance. The participants proceeded to read the protocol's instructions on their own and commenced with the test.

After each participant completed the test, they were allowed to leave. Each participant was informed that by taking the test, they gave consent to participate in the experiment and was given a copy of the consent form. Each participant was assured the results would remain anonymous and was asked to maintain secrecy due to the ongoing nature of the tests. Each person was thanked personally for their participation.

Each participant was required to read the instructions for the test, write the route description on the provided sheet, and then answer the questions described above. Participants were given 20 minutes. However through the course of testing it became apparent, through direct observation, that participants with the overlay graphics took less time than some participants who had the image or map graphic.

Through approximately 30 sessions of testing, the average number of participants in each session was 12. Sessions were added because there was a concerted effort to increase the number of male participants in order to obtain balanced cells for the between subjects ANOVA. A discussion regarding the problems of recruiting male participants will be addressed in the next chapter. There was a total of 279 participants.

3.3.5. Data Transcription

Route descriptions were transcribed using Dragon Naturally Speaking 10.0 (Nuance Communications, Burlington, MA) and all digital files were saved in rich text file (RTF) format. Transcription errors were fixed manually. The data from the questionnaire were hand coded using Open Office Calc 2.5 and 3.0 (Oracle, Redwood Shores, CA).

Due to ATLAS.ti being cost prohibitive for text analysis during the current experiment, the textual analysis phase was performed using a series of shell scripts in the Cygwin environment running under Windows 7 (Microsoft Corporation, Redmond, WA). Text strings such as variants of landmark names, turn types (left, right), cardinal directions (north, south, east, west), street names (ie Broad, Cross, or Thru) and distance indicators (meters) were filtered through the Bourne again shell (BASH) grep (grab regular expression) command. An ASCII-encoded file was created from the individual output files from the grep command. All files were reprocessed to ensure all text strings were captured for future textural analysis.

Landmark identification features for test graphics that did not have labels were interactively identified by this researcher. Any environmental feature that was identified as a reasonable description by this researcher was counted as a landmark. For example, any variation of track or high school field was identified as the *Track Field.* Another example was for *City Lake Park* where any variation of descriptions of a park, lake, or golf course were counted as that landmark.

A skeletal description coding scheme was developed to determine description errors for distances, directions, and segments. All test participants' descriptions were processed an additional step to determine errors as described above as well as start, stop, t-intersections or dead-ends, and serial listings. The following is the route description showing distances and directions. Parenthesis statements designate cardinal directions, and brackets designate non-standard distance estimators:

1. Start at point A, left (west) of the High School, and travel west on B St for 200m [1.5 blocks, 0.2 mi]

2. Turn right (northwest) on Broad St and travel 800m [5 blocks, 0.5 mi], passing District Court on left (west) and Baseball Field on right (east)

3. Turn slightly right (north) on Broad St and travel less than 50m [<0.5 blocks, 164 ft]

4. Turn left (west) on G St and go 500m [5 blocks, 0.3 mi, 1640 ft]

5. Turn left at the Arts Center (south) on 15th St for 450m [4 blocks, 0.28 mi, ̃1476 ft] passing through City College and dead-end at Forest Park

6. Turn left (east) on Forest Park Dr for 250m [2 blocks, 0.15 mi, 820 ft] following Forest Park to your right (south)

7. Turn right (southwest) on Thru St and go 200m [2 blocks, 0.12 mi, 656 ft] following Forest Park and end at point B

Please use the following space below to describe how you would travel along the highlighted route starting at point A to point B. Write the description as if you are *giving directions to another person* who is unfamiliar with the route.

FIGURE 3.6. Experiment 1 Page 1 protocol.

Please answer the following questions regarding the graphic that shows the highlighted route. Circle the answer that best identifies your opinion.

1. Is this graphic a map?

1	2	3	4	5
not at all a map				definitely a map

2. If you were physically in this town, how confident are you that you could navigate from Point A to Point C using this graphic?

1	2	3	4	5
not at all confident				extremely confident

3. Would you want to use this graphic (or one comparable for another area) as a tool to navigate through an environment?

1	2	3	4	5
no never				yes frequently

4. Is there another type of graphic you would prefer? Yes or No (circle one)

   a. If so then what type? ______________________________

5. How easy was this task you just performed?

1	2	3	4	5
very difficult				very easy

6. In general, how confident are you in your ability to navigate with a map?

1	2	3	4	5
not at all confident				extremely confident

7. Would this graphic (or one comparable for another area) be helpful for giving you a sense of the place?

1	2	3	4	5
no not at all				yes very helpful

   a. How would this graphic be helpful (or not helpful) for giving you a sense of the place?

____

____

FIGURE 3.7. Experiment 1 Page 1 questionnaire.

8. Do you recognize the geographic area in the graphic that shows the highlighted route?

   Yes or No (circle one)

   a. If yes, where is it? ____

   b. What is the level of your familiarity with the place? (circle one)

      just recognize it   visited once   visit frequently   lived there

Please complete the following questionnaire about yourself.

1. Age __________

2. Male or Female (circle one)

3. Occupation ____

   a. If a student, what major ____

4. Check any of the occupations below in which you have worked and indicate how long you worked.

√	Occupation	Years
___	Census Taker	______
___	Delivery or Route-based person	______
___	Forest Ranger	______
___	Geoscientist	______
	Military personnel	
___	Branch/MOS____________________	______
___	Pilot	______
___	Public Safety personnel	______

5. Do you participate in any of the following recreational activities? Check all that apply and indicate how often.

√	Activity	Days per Year
___	Boating	__________
___	Geo-caching	__________
___	Hiking	__________
___	Orienteering	__________
___	Piloting	__________

FIGURE 3.8. Experiment 1 Page 2 questionnaire.

This concludes the test. Thank you for your participation.

FIGURE 3.9. Experiment 1 Page 3 questionnaire.

FIGURE 3.10. Test graphic number 1 for Experiment 2 (Image) depicting basic layout with route path from point A to B. The white cross symbol has been eliminated from the graphic.

FIGURE 3.11. Test graphic number 2 for Experiment 2 (Image Overlay without Labels) depicting basic layout with route path from point A to B. The white cross symbol has been eliminated from the graphic.

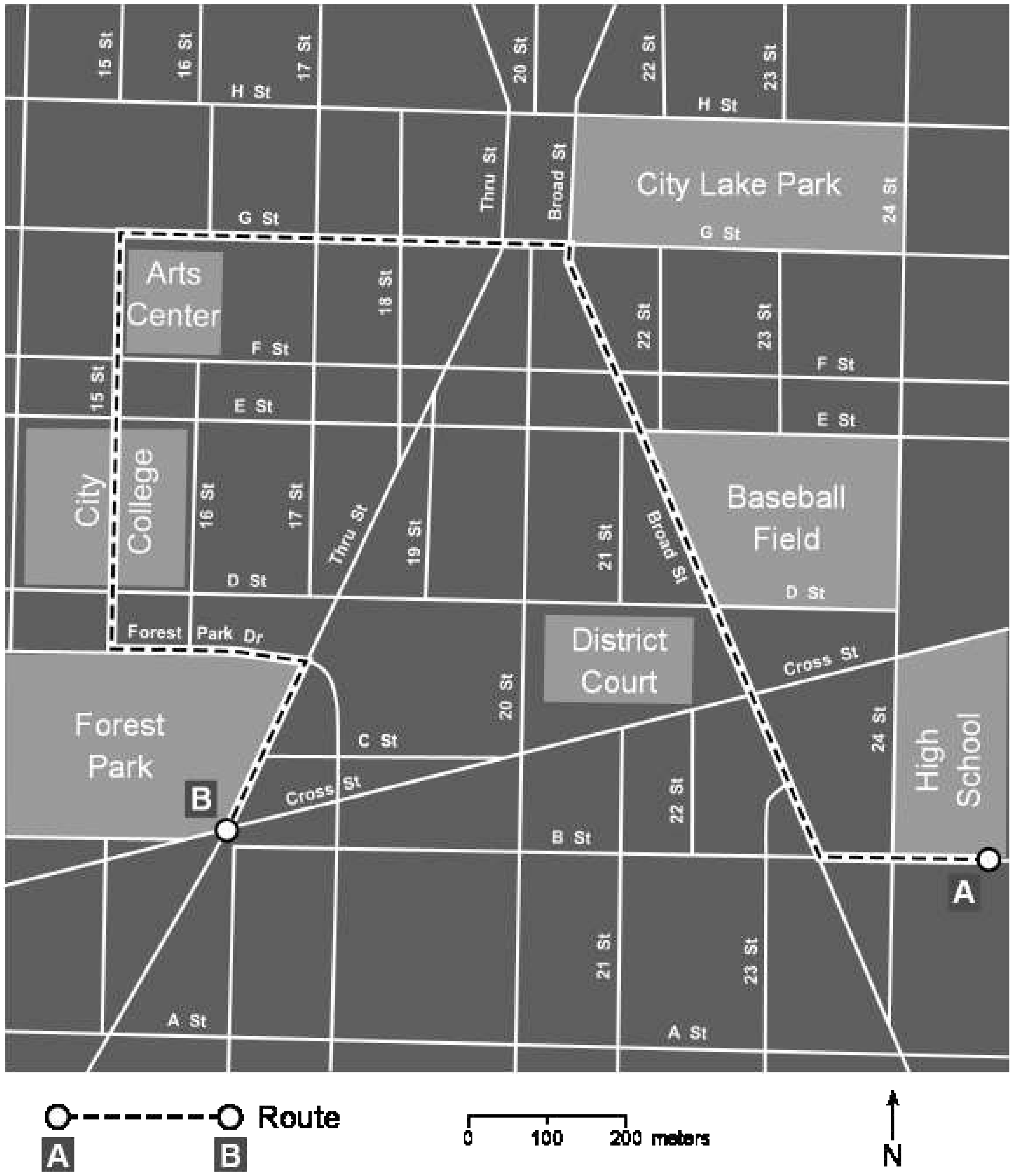


FIGURE 3.12. Test graphic number 4 for Experiment 2 (Map) depicting basic layout with route path from point A to B. The *City College* can be seen in the lower left of the map graphic.

FIGURE 3.13. Test graphic number 3 for Experiment (Map Overlay with Labels) depicting basic layout with route path from point A to B. The *City College* can be seen in the lower left of the map graphic.

Please use the following space below to describe how you would travel along the highlighted route starting at point A and traveling to the final destination at point B. Write the description as if you are *giving directions to another person* who is unfamiliar with the route.

- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____
- ____

FIGURE 3.14. Experiment 2 protocol.

Please complete the following questionnaire. Please circle the most appropriate answer where indicated.

1. Age: __________
2. Sex: M   F
3. Major ____
4. Number of Geography courses taken. High School: _____________ College: _______________

	almost never	once in a while	somewhat often	fairly often	very often
5. Do you use maps?	1	2	3	4	5
6. Do you get lost in unfamiliar cities?	1	2	3	4	5
7. Do you use Internet map programs?	1	2	3	4	5
8. Do you use landmarks when giving *verbal* directions?	1	2	3	4	5
9. Do you use landmarks when giving *written* directions?	1	2	3	4	5

	not at all	a little	somewhat	fairly	very
10. Are you confident with map reading?	1	2	3	4	5
11. Are you confident with your sense of direction?	1	2	3	4	5
12. Are you confident navigating with a map?	1	2	3	4	5
13. Are you confident using Internet mapping programs?	1	2	3	4	5
9. Were you confident using the current map?	1	2	3	4	5

This concludes the questions. Thank you for your cooperation.

FIGURE 3.15. Experiment 2 questionnaire.

CHAPTER IV

RESULTS & DISCUSSION

4.1. Experiment 1 Results

4.1.1. Demographic Response Results

A total of 92 responses were used from the original 113 participants. A total of 17 participants results were not included in the initial analysis; 10 participants' responses could not be used due to test instrument contamination, and seven took the test before. Four participants' responses were eliminated from the analysis because they did not follow the test protocol directions. Age ranges for the 92 participants in the current study was 19 to 36 (M = 23.11, SD = 4.18). Forty-eight males and 44 females were included in the analysis.

The majority of respondents self-identified themselves as students (84 out of 92, or 91.3%). See *Table 4.1* on page 55 for a list of occupations. The majority of participants listed their majors as Geography (36) or Environmental Studies (22). The majority of participants were University of Oregon students affiliated with the geography field as seen from the two tables, *Table 4.2* on page 56.

Participants were prompted to answer in the affirmative whether they participated in activities the research team anticipated would be related to map reading. Another aspect of the questionnaire asked how many years of experience the test subject had in each activity. The first response matrix question related to occupation, *Table 4.3* on page 57. However, given the majority of the participants identified themselves as students, affirmative occupation responses were extremely low. Subsequent use of the occupation question was eliminated from future analyses. The second response matrix question was

TABLE 4.1. Experiment 1 Occupation Responses

Occupation	*f*	Cum. %	Occupation	*f*	Cum. %
Student	84	91.3	Nanny	1	96.8
Archaeologist	1	92.4	Retail Management	1	97.9
Bookkeeper	1	93.5	Ski lift construction	1	99.0
Direct Care Professional	1	94.6	Teacher	1	100.1
Instructor	1	95.7			

related to recreational activities that, once again, the research team identified with map use.

Participants were prompted to answer to all items that applied to the stated activities. As seen in *Table 4.4* on page 57, response rates were higher than the occupation matrix questionnaire with many participants answering in the affirmative. However, positive response rates were generally disappointing to see, and the recreational activities questionnaire matrix was not used in subsequent analyses.

4.1.2. Likert-Scale Analysis

4.1.2.1. Reliability Analysis

A post-hoc internal consistency analysis was performed on first section of participants' opinions of using the test graphic using the six Likert questions. A Cronbach's alpha of .56 was obtained. This shows that the opinion questions have little internal consistency; thus using the Likert-scale questions for further statistical analysis must be taken with caution.

TABLE 4.2. Experiment 1 University of Oregon Major Responses

Major	f	Cum. %	Major	f	Cum. %
Geography	36	39.1	Economics	1	90.2
Environmental Studies	22	63.0	Philosophy	1	91.3
Biology	8	71.7	Architecture	1	92.4
Science	4	76.0	Marine Biology	1	93.5
Undeclared	4	80.3	Interdisciplinary	1	94.6
Public Policy & Management	2	82.5	Sociology	1	95.7
Journalism	2	84.7	Public Health	1	96.8
Advertising	1	85.8	Business	1	97.9
Anthropology	1	86.9	Geology	1	99.0
Art History	1	88.0	None stated	1	101.1
Chemistry	1	89.1			

4.1.2.2. Correlation Statistical Analysis

Spearman rank correlation statistics were generated using a two-tailed test of significance given no a priori assumptions see *Table 4.5* on page 58. Moderate correlations (Cohen, 1992) with significant results are seen with the questions related participants' confidence using the current graphic and maps in general. The first moderate correlation (r = .40, $p < .01$) is seen between the questions related to whether participants were confident using the current graphic (Q2) and whether they considered the task they performed to be easy (Q5). Two other moderate correlations (r = .34, $p < .01$) are seen between confidence using the current map (Q2) and map navigation confidence (Q6); as well as whether participants wanted to use the graphic for navigation purposes (Q3) and if the current graphic was helpful to give them a sense of place (Q7).

TABLE 4.3. Experiment 1 Occupation Response Matrix

Occupation	Responses	Missing Data	Response Rate (%)
Census Taker	0	92	0.0
Delivery or Route-based person	15	77	16.3
Forest Ranger	0	92	0.0
Geoscientist	3	89	3.3
Military personnel	3	89	3.3
Pilot	1	91	1.1
Public Safety personnel	3	89	3.3

TABLE 4.4. Experiment 1 Recreation Response Matrix

Recreation Activity	Responses	Missing Data	Response Rate (%)
Boating	40	52	43.5
Geo-caching	8	84	8.7
Hiking	77	15	83.7
Orienteering	12	80	13.0
Piloting	1	91	1.1

TABLE 4.5. Experiment 1 Inter-item Correlation Scores for Likert-scale Questions

Scale	1	2	3	4	5	6
Q1: Map?	—	.09	.28**	.11	.10	.11
Q2: Confident with this graphic?		—	.29**	.40**	.34**	.13
Q3: Want to using this graphic?			—	.24*	.03	.34*
Q5: Easy task?				—	.18*	.14
Q6: Confident using maps?					—	.20*
Q7: Graphic helpful?						—

* $p < .05$

** $p < .01$

Weak correlations with significance at the .01 level are on items associated with participants' opinions whether they wanted to use the test graphic(s) for map navigation are seen. There is a moderately weak correlation between confidence using the current map (Q2) and whether participants wanted to use the graphic for navigation (Q3), r = .29, $p < .01$. Similar results are seen regarding whether participants thought the graphic they were using was a map (Q1), and if they wanted to use the current map for navigation (Q3), r = .28, $p < .01$.

Other moderately weak correlations are seen related to participants thought the experimental task was easy. There is a moderately weak correlation with whether participants wanted to use their test graphic for map navigation (Q3) and whether they thought the task was easy (Q5), r = .24, p =.01. Similar results are seen (r = .18, p = .05) between participants' opinions on the ease of the task (Q5) and whether they were confident using maps (Q6). Another result is seen whether participants were confident

TABLE 4.6. Experiment 1 Factor Loadings for Exploratory Factor Analysis with Varimax Rotation of Likert-scale Questions

Scale	Opinion	Confidence
Q1: Map?	.28	.07
Q2: Confident with this graphic?	.24	**.73**
Q3: Want to using this graphic?	**.99**	.07
Q5: Easy task?	.21	**.46**
Q6: Confident using maps?	.00	**.47**
Q7: Graphic helpful?	.33	.13

Note: Factor loadings $>$ .40 are in boldface.

using maps (Q6) and whether their test graphic was helpful to give them a "sense of place" (Q7), r = .20, p = .03.

4.1.2.3. Exploratory Factor Analysis

An exploratory factor analysis using maximum likelihood analysis with a varimax rotation was performed to determine if the above Likert-scale questions detected any underlying latent variables (Costello and Osborne, 2005). Two factors were identified with 52.35% of variance explained based on the initial eigenvalues and 37.97% based on the rotation method. This reflects the lack of strong correlations and communalities between the Likert questions. The first factor identified is associated with questions regarding participants' opinions on the test graphic associated with whether participants preferred to use the current test graphic (Q3), whether participants believed the current test graphic was helpful with giving them a sense of place (Q7), and if they believed the current test graphic was a map (Q1).

Three questions related to confidence are identified with factor 2. The first two are associated with whether participants were confident using the test graphic (Q2) and whether they were confident using a map for navigation (Q6) loaded on this factor. The opinion question regarding whether participants believed the task was easy (Q5) was problematic given it loaded on the confidence factor but also associated with the first factor, the opinions on the current map and map use.

4.1.3. Dichotomous Opinion Questions

Question 4 prompted participants' opinions whether they preferred another graphic where 40% answered the affirmative. An exploratory analysis was conducted using logistic regression to determine if test graphic type influenced subjects' response. A statistically significant result was seen at the .01 level. More participants using the image test graphic preferred another map type than the current one where approximately 72%, or 21 out of 25, answered in the affirmative. Participants using the map overlay (72% or 18 out of 25) or the map (76% or 29 out of 38) answered they did not prefer another test graphic, *Figure 4.1* on page 61.

Question 8 prompted participants' opinions whether they recognized the location. Remember from the previous chapter that the research team deliberately manipulated the base image to prevent test subjects adversely affecting the outcome of their answers. The majority of participants (87%) answered they did not recognize the location.

4.1.4. Landmark Usage Statistical Analysis

Descriptive statistics for measures of central tendency and dispersion were performed on participants' description of landmarks for the route description section of the test. A total of 48 male and 44 female scores were tabulated. There were 18 males and

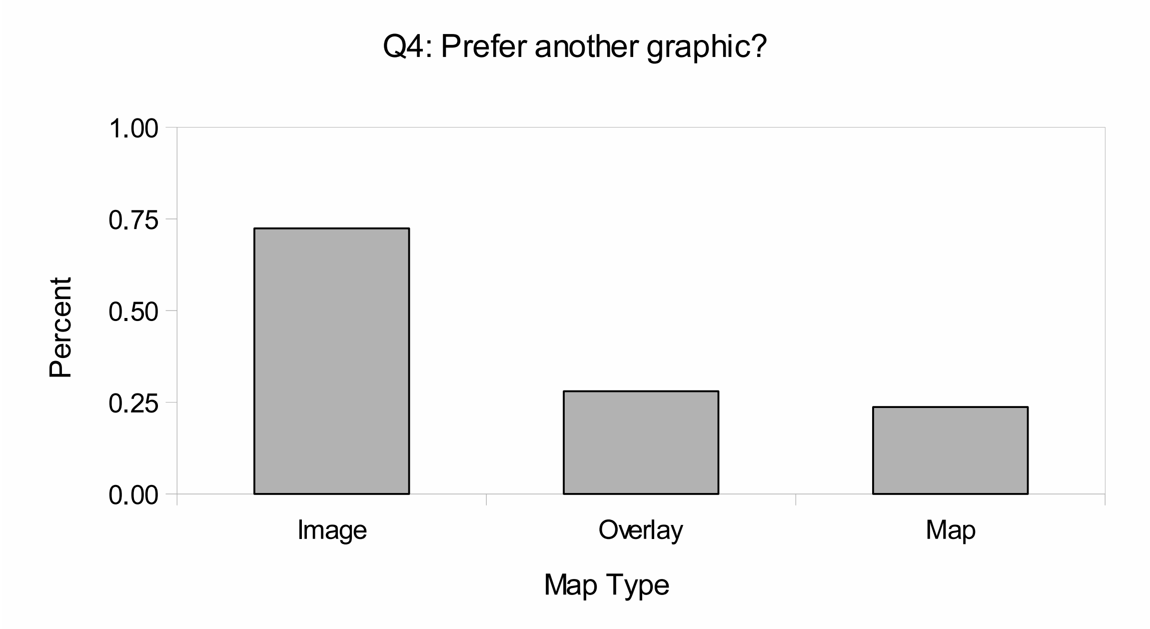


FIGURE 4.1. Response percentages on whether participants preferred another test graphic based on map group.

11 females in the image group, 12 males and 13 females in the map overlay group, and 18 males and 20 females in the map group.

Mean landmark usage comparing males and females based on map type shows the image group males (M = 3.28, SD = 1.40) and females (M = 3.55, SD = 1.44) do not differ much. Similar results are seen for the map group where males described similar number of landmarks (M = 3.50, SD = 1.95) compared to females (M = 4.00, SD = 2.13). The map overlay group described less landmarks than the image and map groups where males (M = 0.58, SD = 0.90) and females (M = 0.38, SD = 0.65) described, on average, less than one landmark in the route description test, see *Figure 4.2* on page 63.

A graphic comparison showing the difference in total number of landmarks described for each test graphic can be seen in *Figure 4.3* on page 64. Previous literature states that salient landmarks at the start and end of a route are important in order for these to be used as anchors in the landscape (Couclelis et al., 1987; Golledge and Spector, 1978). Descriptive comparisons were conducted using the previous research as a foundation to determine differences between the sexes and map type. In fact, the image and map test graphics had more participants describe these landmarks compared to the map overlay.

More males in the image test graphic group described the *School Track* (10) than females (5). Similar results are seen comparing males (12) and females (4) described the end landmark *Forest Park*. However, more females described the first landmark in the map test graphic group at 15 compared to 10 males. Likewise with the last landmark where 19 females described *Forest Park* compared to 16 males. Contrast the above results with the map overlay test graphic shows males and females equally described the first landmark (males = 2, females = 2) and the last (males = 3, females = 4).

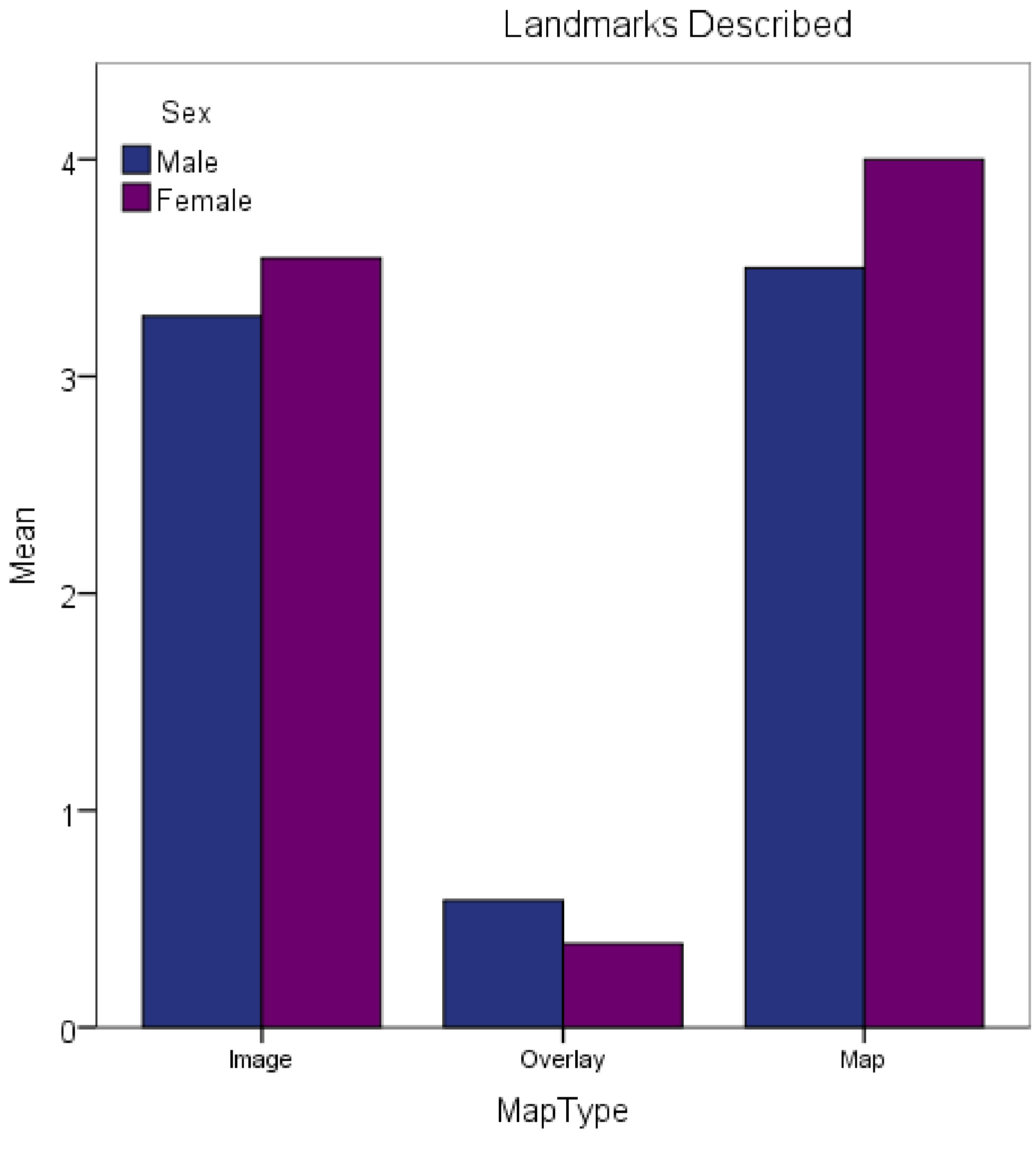
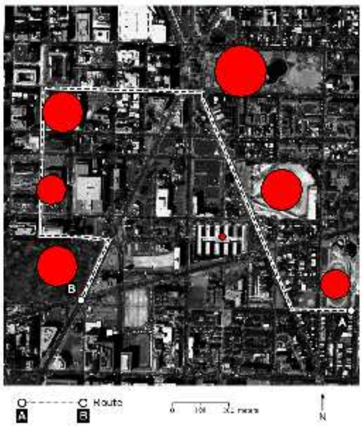


FIGURE 4.2. Experiment 1 mean landmark usage per test graphic type grouped by sex.

a. Test Graphic 1: Image

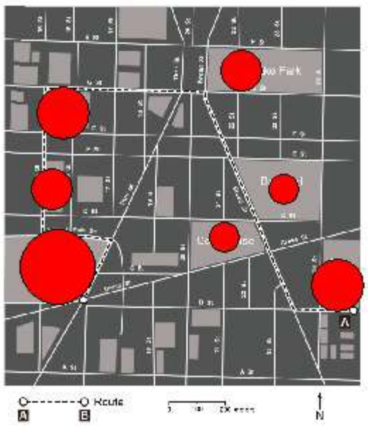


Feature	M	F	Total
School Track	10	5	15
Courthouse	0	1	1
Baseball Field	10	7	17
City Lake Park	14	7	21
Arts Center	13	6	19
Hospital	4	7	11
Forest Park	12	4	14
Totals:	63	37	98

b. Test Graphic 2: Map Overlay

Feature	M	F	Total
School Track	2	2	4
Courthouse	0	0	0
Baseball Field	0	1	1
City Lake Park	0	0	0
Arts Center	2	0	2
Hospital	0	1	1
Forest Park	3	4	7
Totals:	7	8	15

c. Test Graphic 3: Map



Feature	M	F	Total
School Track	10	15	25
Courthouse	4	7	11
Baseball Field	7	7	14
City Lake Park	10	10	20
Arts Center	9	13	22
Hospital	8	11	19
Forest Park	16	19	35
Totals:	64	82	146

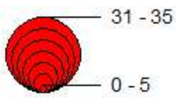


FIGURE 4.3. Experiment 1 landmark descriptions results for each test graphic type. Circle sizes represent total counts for each landmark. Tables display male (M) and female (F) description comparisons plus total counts.

A post-hoc two-factor between-subjects analysis of variance (ANOVA) was performed with the independent variables sex as a fixed factor and map type as a random factor. The ANOVA was performed using the independent variables and the number of landmarks as the dependent variable described by participants using Type III sum of squares. A statistically significant main effect was found for map type, $F(2, 546) = 96.41$, $p = 0.01$, partial $\eta^2 = .99$. There was no significant main effect for sex, $F(1, 546) = 0.83$, $p = 0.45$, partial $\eta^2 = .28$; and no significant interaction between map type and sex, $F(2, 546) = 0.36$, $p = 0.70$, partial $\eta^2 = .01$.

Post-hoc comparisons of the different map types were performed on landmark usage. Because variances were assumed to be heterogeneous, Tamhane's T2 post-hoc multiple comparisons test was performed on mean landmarks in each map type (Tamhane, 1979). There was a statistically significant difference between test participants' mean use of landmark descriptions between the image and image overlay, where $F_{T2}(2, 91) = 3.29$, $p < .001$, 95% CI [2.27, 4.30]. Participants provided more landmark descriptions in the image compared to the image overlay. A similar result was found comparing landmark usage between the map and image overlay, $F_{T2}(2, 91) = 3.64$, $p < .001$, 95% CI [2.61, 4.67]. More participants described landmarks when using the map compared to participants using the image overlay. The post-hoc comparison between the image and map showed no statistically significant difference between describing landmarks, $F_{T2}(2, 91) = -0.31$, $p = .87$, 95% CI [-1.58, 0.88]. Test participants in both groups described similar numbers of landmarks for their route description tasks, *Figure 4.4* on page 66.

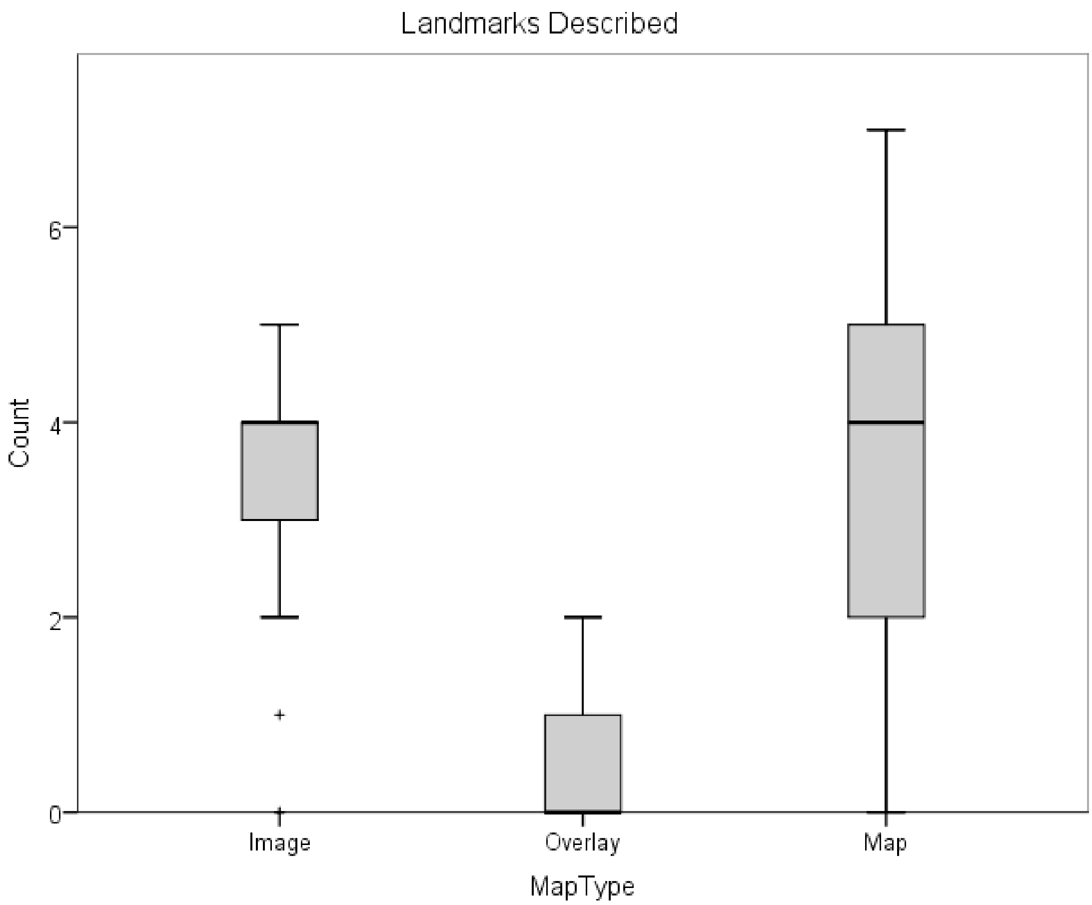


FIGURE 4.4. Experiment 1 landmark usage showing means and ranges.

4.1.5. Spatial Information Statistical Analysis

Post-hoc analyses regarding whether males differ from females using specific environmental descriptors were conducted. Research hypotheses were formulated that males would use meters for the distances and cardinal directions when describing the route more than females. Females, in contrast, would use left/right turn types and non-standard distances more than males.

Student's *t*-statistics were used to compare the means between males and females for the environmental descriptors. For the linear distance estimator, there was no statistically significant difference, $t(90) = -0.48$, $p = .63$ (two-tailed), between males ($M = 0.35$, $SD = 1.11$) and females ($M = 0.47$, $SD = 1.2$), see *Figure 4.5* on page 68. There was no statistically significant difference between males ($M = 0.31$, $SD = 0.82$) and females ($M = 0.51$, $SD = 1.39$) using cardinal directions either, $t(90) = -0.88$, $p = .38$ (two-tailed), *Figure 4.7* on page 70. Females ($M = 4.84$, $SD = 0.65$) did not differ from males ($M = 4.55$, $SD = 1.34$) when using left/right turn types, $t(90) = 1.27$, $p = .20$ (two-tailed), see *Figure 4.6* on page 69. Nor was there any statistically significant difference, $t(90) = -.66$, $p = .51$ (two-tailed), between males ($M = 1.98$, $SD = 2.09$) and females ($M = 1.70$, $SD = 1.96$) when using nonstandard linear distances estimators, see *Figure 4.8* on page 71.

Spatial knowledge scores were compiled based on test participants' types of spatial descriptors. No males or females used survey descriptors (standard linear distances and cardinal directions) exclusively. Thirty-three males and 30 females used route (left/right turns and landmarks) descriptors only; whereas, 16 males and 13 females used mixed methods of route descriptors. The results showed that comparable numbers of males and females described the test routes in the similar manner.

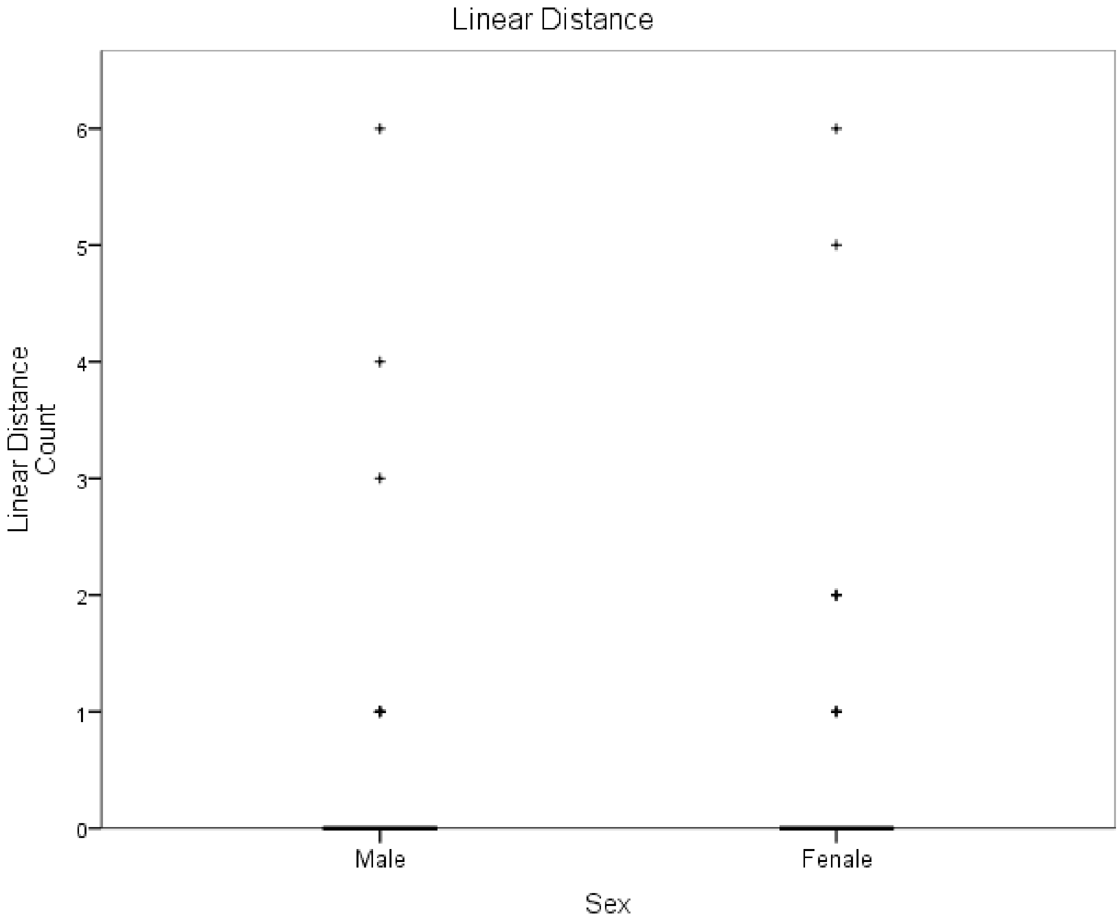


FIGURE 4.5. Experiment 1 distance usage showing means and ranges.

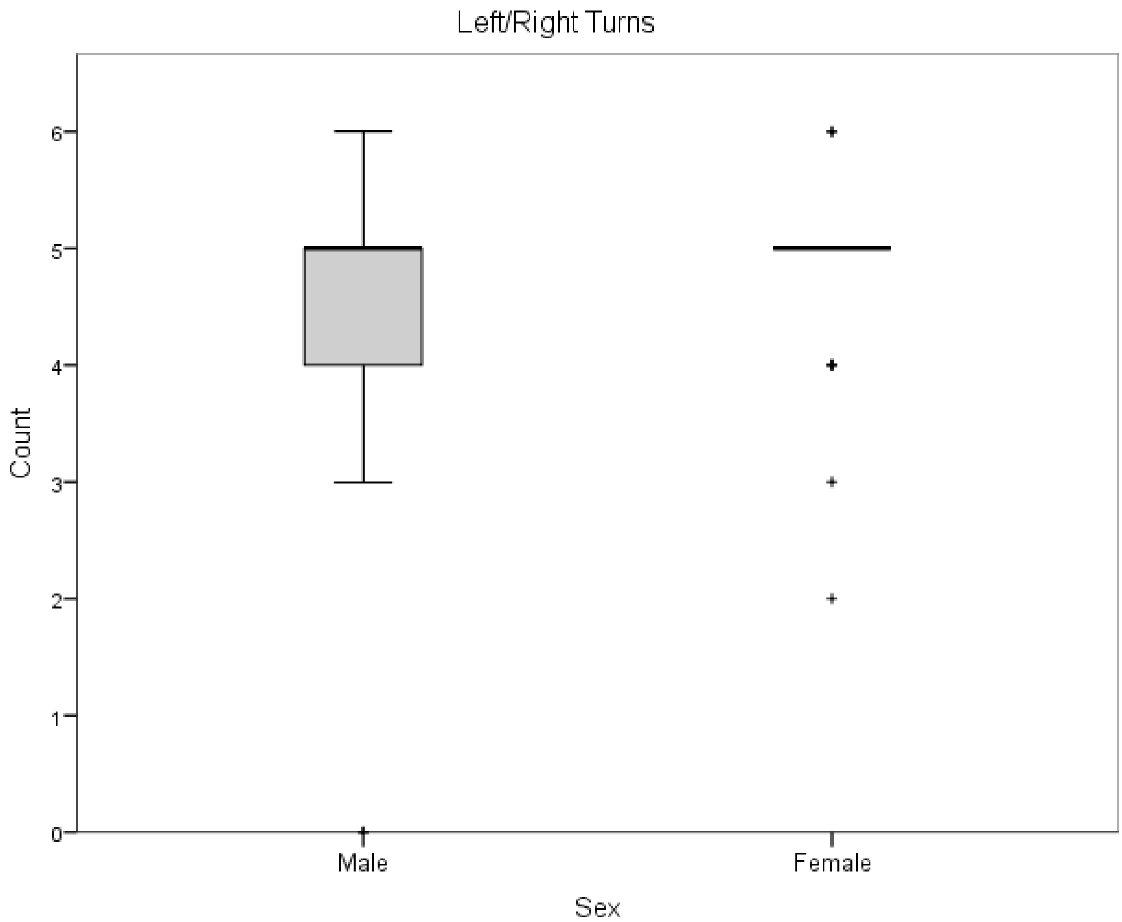


FIGURE 4.6. Experiment 1 left/right turn counts by sex showing means and ranges.

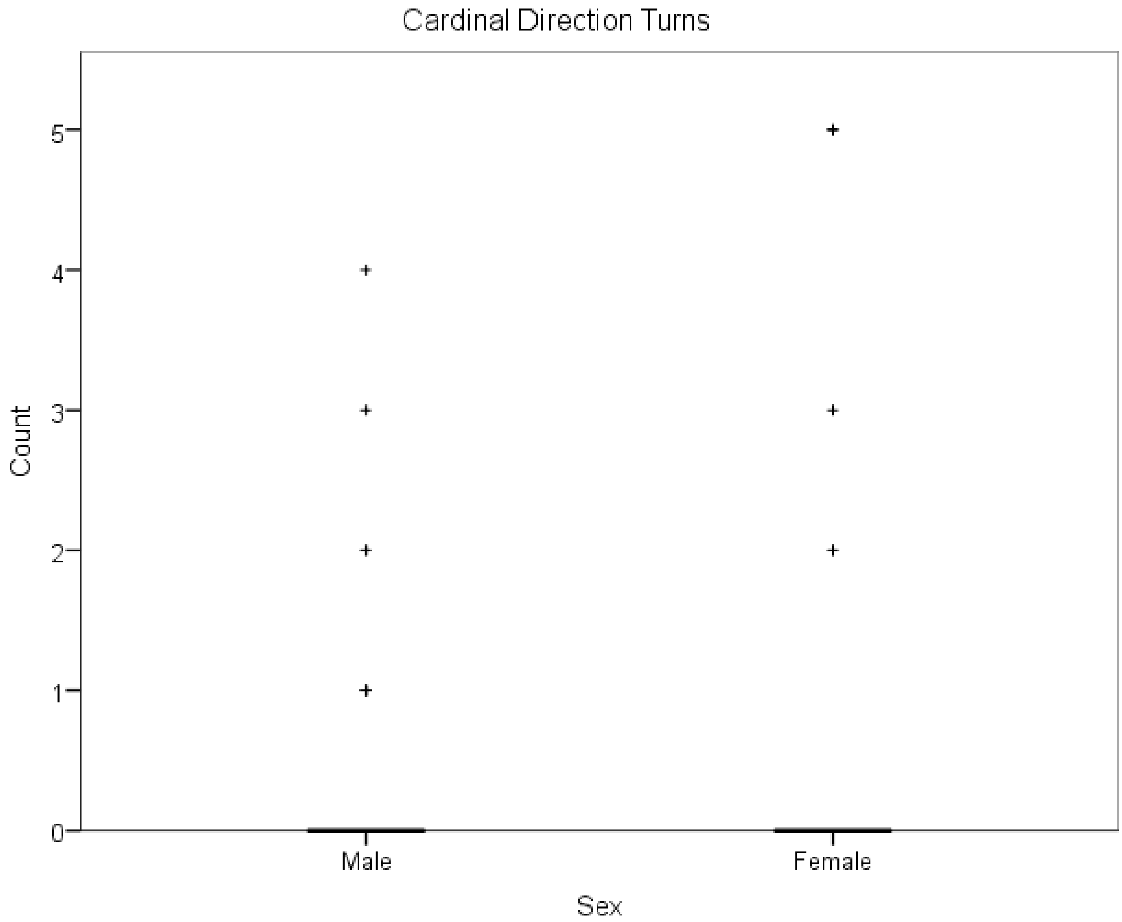


FIGURE 4.7. Experiment 1 cardinal direction turn counts by sex showing means and ranges.

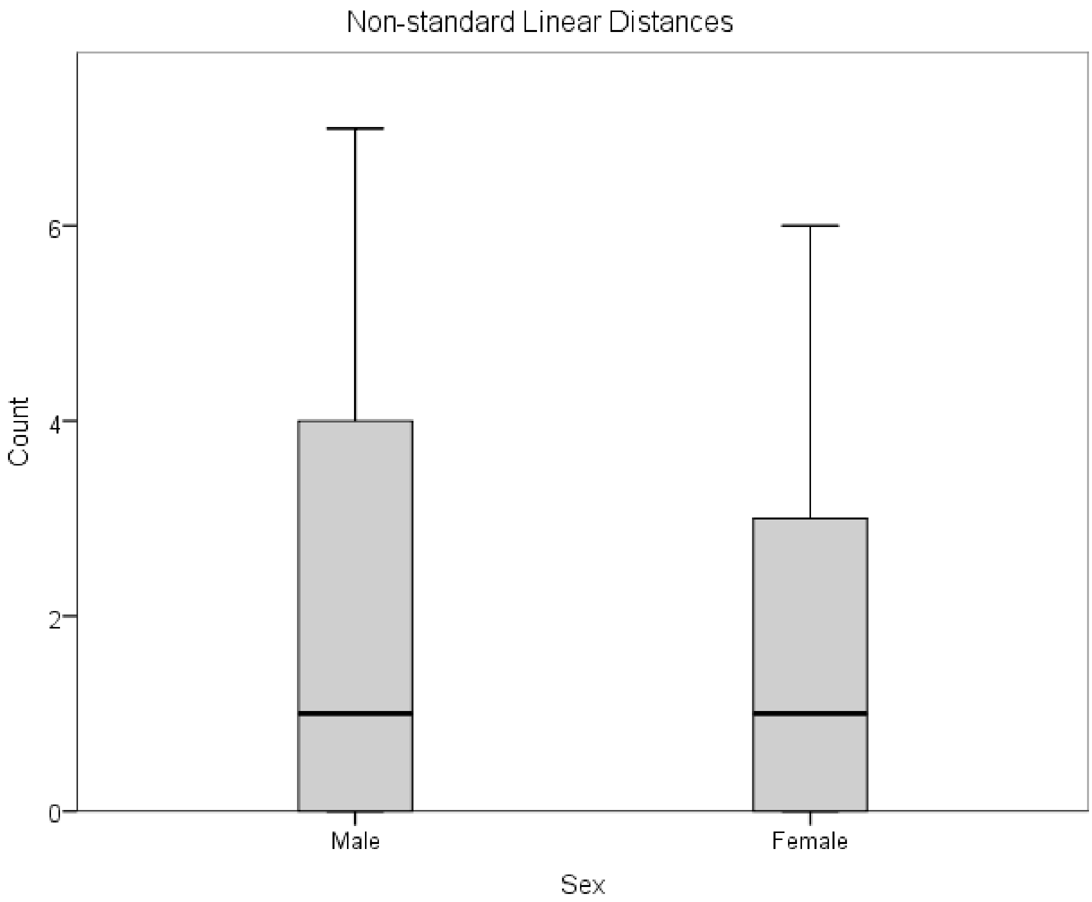


FIGURE 4.8. Experiment 1 non-standard linear distance counts by sex showing means and ranges.

Descriptive statistics were compiled based on map type. As seen from above, no participant used survey knowledge descriptors exclusively. All participants used either route or mixed route-survey knowledge descriptors. More participants used route descriptors compared to the mixed method; where similar methods were used for the image group (23 versus 6) and the map group (25 versus 13). The map overlay group of participants was closely matched where 15 used route and 10 used mixed spatial knowledge descriptors, *Figure 4.9* on page 73.

A post-hoc ANOVA was conducted on the research hypothesis that map type and not sex determines the type of spatial information descriptors that was used to describe the route. The independent variables were sex and map type. The dependent variable was spatial knowledge type with the two identified levels. No statistically significant result was seen for sex at the .01 level, $F(1, 91) = 0.07$, $p = .82$, partial $\eta^2 = 0.03$. No statistically significant result was seen for the map type either, $F(2, 91) = 1.29$, $p = .44$, partial $\eta^2 = 0.56$. The interaction between sex and may type showed no statistically significant results as well, $F(2, 91) = 0.93$, $p = .40$, partial $\eta^2 = 0.02$.

The previous experiment was exploratory; whereas the next one was specifically designed as a pseudo-experimental design using ANOVA with a redesign of the demographic questionnaire and the introduction of a fourth map to tease out whether map type—with or without landmark labels interact with test subjects landmark descriptions.

4.2. Experiment 1 Discussion

4.2.1. Test Administration

Issues and concerns this researcher had concerned whether external stimuli influenced the outcomes of the experimental results. Some testing conditions were not conducted in optimal conditions where test pool answers were contaminated, outside

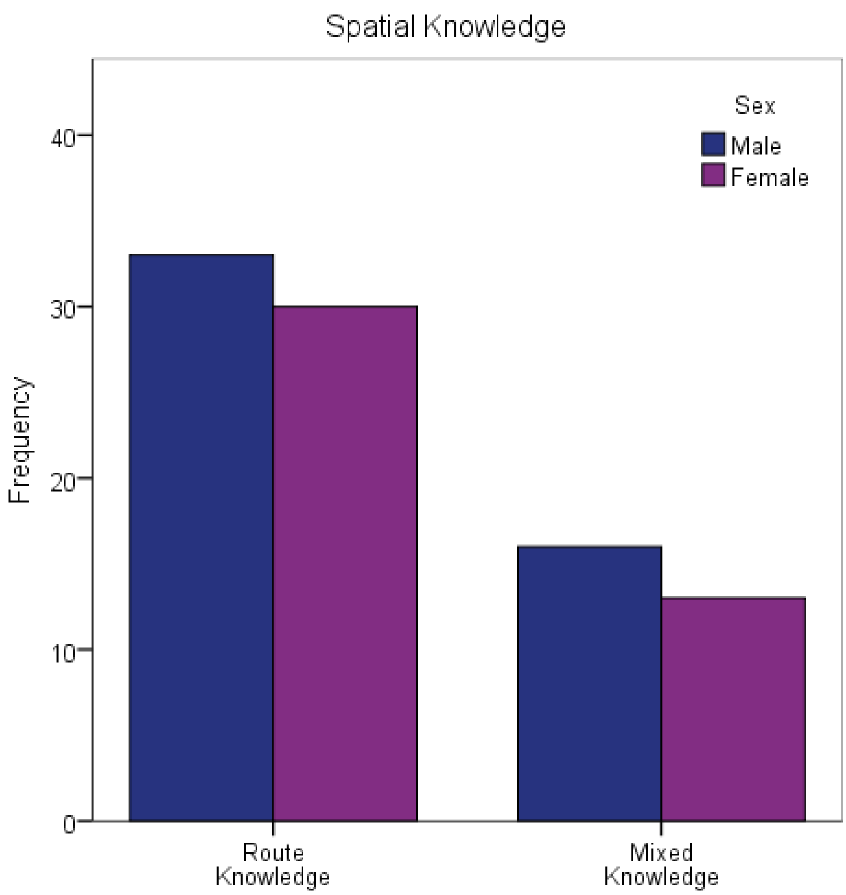


FIGURE 4.9. Experiment 1 frequency counts for spatial knowledge type grouped by sex.

influences could have adversely affected participants testing environment experience, and test reactivity from using a test pool from primarily University of Oregon students taking geographic classes. The following paragraphs describe testing conditions that could have influenced the outcome of the results.

The first test session room, Pacific 217, is a meeting/geography graduate student office with tables where approximately 10 to 12 students sit facing one another. Because the first testing room is also a graduate student office, other persons not associated with the sessions were present and conversing with other students within earshot of test participants.

The second test session is MacKenzie 442, the Social Sciences Instructional Laboratory (SSIL) computer laboratory. There are approximately 34 large computer monitors and students sit in front of the computer terminal forward facing. From the outset the testing conditions between the two rooms were not comparable. This eventually proved to be problematic in one test session in Pacific 217. During one session, others not connected with the experiment were conversing loudly. Thus this became a threat to internal validity of the experiment due to auditory distractions out of the control of the experimenters.

During one session in Pacific 217, the test packets were mixed and all participants became aware that test graphics were not the same. Once the participants realized there was more than one test instrument, testing stopped. Test administrators were concerned that participants' responses would be contaminated by the influence of seeing the other graphic, and the 10 participants' responses were eliminated from final analysis. Test sessions in the Geography 311 group revealed seven participants previously took part in the Geography 323 group. These participants had to be eliminated from the pool used for statistical analysis.

A concern from this researcher was whether using geography students that were familiar with the researchers could affect the outcome of the results, known as reactivity in psychological research methods. Were the results a function of participants unknowingly anticipated what the University of Oregon researchers were interested in. If the results were due to this effect, then would using a new research test participant pool have different results?

The next experimental design addressed the problems from the University of Oregon testing sessions where the test pool was recruited from the San José State University Psychology department general test pool, and a testing room was dedicated for all sessions. The goal was to ensure no test participant knew the principal researcher prior to testing.

4.2.2. Demographic Questionnaire Design

The University of Oregon researchers were not sure what the outcome of the experiment would be, and preliminary analysis revealed surprising results regarding landmark usage in route descriptions. Preliminary results indicated landmark usage was a function of map type. But the current questionnaire did not ask participants if they usually used landmarks in route descriptions. The next experiment addressed that shortcoming by introducing two questions on landmark usage in the Likert-scale question section.

Other questions arose about the questionnaire such as if the test was capturing data on experience. Remember the University of Oregon study included questions on occupation and recreation specifically targeting persons that would most likely come in contact with maps on a daily basis. However, preliminary analysis revealed that the majority of participants did not respond to questions regarding occupation. Eighty-eight out of 94 participants responded they were students.

Only 16% of the participants responded to the “delivery” category indicating at one time they were employed in that field. The rest of the response rates were well below 5% in the occupation categories. In the recreation category, 42% participants responded they participated in boating, 9% geocaching, 82% hiking, 13% orienteering, and 2% responded they participated in piloting. These banks of questions were subsequently removed from any analysis due to low response rates, and the test bank was removed for Experiment 2.

4.2.3. Likert-Scale Question Design

The question bank had six Likert-scale questions related to participants’ opinions regarding the current test graphic, and two dichotomous response questions with open-ended responses. The researchers designed each Likert-scale question with its own scale from 1 to 5, therefore in-hindsight, it was very difficult to organize questions that were parallel in response scales for future statistical analysis. The Likert questions were redesigned for Experiment 2 where questions were organized as general questions scaled the same where 1 corresponded to almost never and 5 to very often. Question 1 from Experiment 1 was in this first bank for Experiment 2. Question 6 from Experiment 1 was included in a second Likert bank for Experiment 2 where all questions were related to confidence and scaled to have parallel responses where 1 corresponded to not at all and 5 to very. Question 2 from Experiment 1 was also retained to be included in the confidence question bank.

Nowhere in Experiment 1’s questionnaire did the researchers ask participants if they used landmarks when giving directions. So two questions were added to Experiment 2 questionnaire. Additional questions were included associated with Internet map usage because Google Maps and similar applications are popular as a source for directions.

The dichotomous response questions in the Likert-type questionnaire were for exploratory purposes to gather data on participants' opinions about the test graphics. Question 4 asked if test subjects would prefer a different graphic. This question was included to see if the test pool of the image group honestly replied they preferred another graphic. Not surprising, most participants in this group reported they would prefer another graphic. In GIScience classes we are taught the raw image is the most problematic of map types. We are taught that image interpretation is very important in order to recognize and identify features. If people are not able go through the process of recognition and identification, then features in the image are meaningless. Thus the image is useless as a map. GIScience students are taught to use imagery as a base layer and produce maps that go through the cartographic manipulation steps thus minimizing confusion.

Question 8 was to determine if the image manipulation was successful and if the participants did not recognize the location. Remember the manipulated image was of Washington, DC, where some features outside the area of interest were included to mask problematic ones such as the Courthouse overlaying Union Station and the railroad tracks. The design team was successful where the majority of participants could not recognize the location. However some test participants wrongly guessed the place was Springfield, OR. This is perhaps because Springfield's street naming convention is similar to the typical American town. Curiously five participants identified the location as "Springtucky," prompting this researcher to consult the U. S. Board of Geographic Names database to determine where such a place existed. To my dismay the aforementioned is a derisive local name for Eugene's neighbor. Questions 4 and 8 were not included in Experiment 2.

4.2.4. Test Graphic Design

A fourth map was designed to determine whether there were differences in a map overlay with landmarks labeled in comparison to a map overlay with landmarks not labeled. Initial results in the pilot study revealed statistically significant differences between the map types. Recently, Internet mapping services have begun to label prominent landmarks on maps. Directions for on-line mapping services such as Google Maps, Microsoft's Bing Maps, MapQuest, and Yahoo Maps are increasingly being used by individuals instead of paper maps. The driving directions in most of these systems do not use landmarks as key features but use egocentric (left, right) turns and distances for directions; however, these mapping services have recently labeled landmarks on their maps.

The landmark for the hospital was reconfigured for all maps in the new experiment because this researcher was concerned a white cross on a pitched roof is not currently used as a standard international symbol. A cursory Internet query of satellite imagery of selected U. S. hospitals (San Francisco General Hospital; Queen's Hospital, Honolulu, HI; Good Samaritan Hospital, San José, CA) show ambulance helipads with large white crosses with a superimposed "H." Thus the white cross was eliminated and the area was relabeled "City College." Many local community colleges in the Santa Clara Valley allow street traffic through campus, and many of San José State University's student population are transfer students from the surrounding colleges. Thus the label was included to determine if some test participants would describe the landmark as a salient feature.

Two landmark features were relabeled. The *Track Field* was renamed as *High School* given the original feature is Dunbar Senior High School in Washington, DC. Another reason for labeling the current feature *High School* is because many U. S. high schools have a track and a field on its grounds, therefore the label would represent a prominent landmark feature rather than a sub-feature of the landmark. The *Courthouse* was relabeled as *District Court* to ensure that all landmarks were identified and labeled as proper nouns. Thus the features were the same with the same footprints, but the labels were changed. The only feature that was expanded in area was *City College* to straddle 15th Street. This was the only landmark to have this attribute.

4.2.5. Statistical Analysis Design

Because Experiment 1 was an exploratory experiment, there was no a priori statistical design decisions. All statistical analysis were preliminary and post-hoc. Original analysis were conducted using descriptive and Chi-squared statistics because this researcher was reticent to use parametric statistical analysis. For the purposes of this monograph, none of the Chi-squared analysis is included.

Correlation statistical results for the Likert-scales were exploratory as well. Many of the correlations were moderate to weakly correlated where the strongest correlation was with the questions related to whether participants were confident using the test graphic and if they thought the task was easy. This was not surprising given the test was conducted in Geography laboratory classes, thus the majority of students would be confident using maps and find the map reading task easy. However, the image test graphic would have brought the statistic down because that graphic was anticipated to be the most difficult to use and therefore, less participants would have been confident.

Correlations were closely tied to participants' opinions on using the test graphic where the question related to whether they were confident using the test graphic (Q2) was correlated to most other questions in the bank. Question 1 (whether participants thought the test graphic was a map) was the most problematic given the majority of correlations were weak with the only moderate correlation between the current question and Question

3 (whether participants would like to use a graphic like the current one). In hindsight, Question 1 does not correspond, nor is matched, with the other questions. Therefore it was not surprising that there were weak correlations between this question and the others. Question 6 (confidence using maps) was another problematic test question.

The post-hoc exploratory factor analysis was the most problematic of the statistical analysis procedures because of the less-than-strict method of designing the Likert-scale questionnaire. Two factors were identified as opinion using the current graphic and confidence. Only one question loaded heavily on opinion, Q3, asking participants whether they wanted to use the current graphic. The factor analysis result was disappointing given only one question loaded on opinion of the current test graphic where other questions except for Q6 (confidence using maps) were weakly associated with this factor.

Three questions loaded on the confidence factor: Q2 (confident with the current graphic), Q5 (was the task easy), Q6 (confident using maps). Question 2 loaded heavily on this factor, and Question 6 loaded on this factor but not at all the opinion factor. Question 5 results should not be surprising because ease of use, although an opinion, should be associated with a person's confidence and comfort level. Question 6, again, was problematic given that it was a general question and not directly related to the task at hand.

Post-hoc analysis of variance was conducted with little regard to whether each cell was balanced. Preliminary results indicate that map type, and not sex, determined whether participants described the landmarks. The results of this analysis was surprising. The greatest determinant was, according to above experiment, map type. The results from Experiment 1 appear to not come to the same conclusion as results obtained from studies by Dabbs, Jr. et al. (1998); Galea and Kimura (1993); Lawton (1994, 2001); MacFadden et al. (2003), and Ward et al. (1986). The above researchers concluded that females used more landmarks in their route descriptions compared to males. However, the current results show that map type determines landmark usage.

The post-hoc ANOVA for spatial information knowledge, route knowledge versus survey knowledge, did not correspond to the above conclusions as well. There were no statistically significant differences between males and females when it came to spatial information knowledge. The majority of participants used route knowledge methods to describe the route where there were no statistically significant differences between males and females when it came to the route knowledge group. Remember that no participant used only survey knowledge to describe the routes. Approximately equal numbers of male and females used route knowledge and mixed methods to describe the route.

The second experiment was designed for a pseudo-experimental design where the main statistical analysis method using a two by four analysis of variance where the independent variables were sex (male and female) and map type (image, map overlay without landmark labels, map overlay with landmark labels, and map). The dependent variable was the average number of landmarks described. All statistical analyses should be not be taken as reliable measures given the exploratory nature of the experiment. The current experiment was redesigned using ANOVA with the target of equal cell sizes and planned comparisons.

4.3. Experiment 2 Results

4.3.1. Demographic Questionnaire Results

A total of 285 test participants from the San José State University (SJSU) Psychology Department Psychology test subject research pools took part in the testing from the Spring semester of 2007 to the Spring semester of 2008. There were 31 test sessions with at least ten to a maximum of 22 participants per session. The majority of subjects came from the General Psychology (Psychology 001) research pool and were granted regular credit for participating in the experiment. Participants from Dr. Sean Laraway's introductory statistics (Statistics 95), Biopsychology (Psychology 30), Advanced Research Methods (Psychology 120), and Psychology of Motivation (Psychology 157) classes were given extra credit. Participants from Dr. Susan Syncerski's Writing Workshop (Psychology 100W) were also given extra credit for participating in the experiment.

Out of the total of 285, 30 participants were eliminated from the analysis due reasons such as two being 17-years-old (below minimum age requirement); one took the test before; nine did not complete the demographic and opinion sections; and 18 gave wrong directions or gave directions from points B to A. Age ranges for the 255 participants was as young as 18 and as old as 57 (M = 21.60, SD = 4.93), where 117 were males and 138 were females. Approximately one-third of participants identified themselves as psychology majors with an additional 11% identifying themselves as nursing students. No geography majors, or other Earth Science majors, took part in the current experiment with only one Environmental Studies student, see *Table 4.7* on page 84.

Two questions were included in the demographic questionnaire related to map reading experience. Recall that Experiment 1 prompted participants to respond whether they partook in employment or recreational activities the research team associated with map reading experience. The two questions included in the current experiment asked to indicate the number of high school or college geography courses the participant took. There was an assumption that exposure to geography classes increased the possibility of participants' exposure to maps and map reading. However, 45% (116 out of 255) of the respondents indicated they never took a high school geography class with another 45%

responded they took at least one, the other 10% responded they took anywhere from two high school geography classes (14 out of 255 or 5%) up to one responding he/she took at least seven classes. The majority of participants, 80% (209 out of 255) responded they took no college-level geography course; Whereas, 16% (42 out of 255) responded they took at least one college-level course, and 1% (4 out of 255) took at least two classes. These questions were not used for any subsequent analyses due to the low response rates and will be addressed in the discussion section.

4.3.2. Likert-Scale Statistical Analysis

4.3.2.1. Reliability Analysis

The Likert-scale questions were grouped based on opinions regarding whether participants used maps (Q5), get lost in unfamiliar cities (Q6), if they used Internet mapping programs (Q7), and whether they used landmarks for verbal directions (Q8) and or landmarks for written directions (Q9). This will be known as the general use section of the Likert questions. The second group of questions were related to confidence when reading maps (Q10), sense of direction (Q11), navigating with maps (Q12), using Internet mapping programs (Q13), and using the current maps (Q14). This second group of questions will be known as the confidence section.

A total of 241 out of the 255 (94.5%) cases were used to analyze the Likert-scale questions. A split-half reliability analysis was performed where the Cronbach's alpha for the confidence section was .84, and the general use section was .35. Given Cronbach's alpha is greater than .80 as a critical value for reliability, the confidence section was determined to be a reliable measure of confidence. However, the general use section was determined not to be a reliable measure.

TABLE 4.7. Experiment 2 San José State University Major Responses

Major	*f*	Cum. %	Major	*f*	Cum. %
Psychology	91	35.7	Radio, Television, Film, and Theater	3	92.2
Nursing	28	46.7	Child Development	2	92.9
Business	18	53.7	English	2	93.7
Undeclared	13	58.8	History	2	94.5
Behavioral Science	11	63.1	Music	2	95.3
Communication Studies	10	67.1	Nutritional Science	2	96.1
Engineering	10	71.0	Sociology	2	96.9
Justice Studies	9	74.5	Communication Disorders	1	97.3
Computer Science	8	77.6	Dance	1	97.6
Kinesiology	7	80.4	Economics	1	98.0
Biology	6	82.7	Environmental Studies	1	98.4
Advertising	5	84.7	Forensic Science	1	98.8
Occupational Therapy	5	86.7	Mathematics	1	99.2
Social Work	5	88.6	Philosophy	1	99.6
Design	3	89.8	Political Science	1	100.0
Journalism	3	91.0			

4.3.2.2. Correlation Statistical Analysis

Spearman rank correlation statistics using a two-tailed test of significance were generated for all combinations of the Likert-scale questions. Many of the questions in the confidence group were strongly correlated. The confidence questions related to map reading, sense of direction, map navigation, and using the current test graphic showed these correlations. The first two questions in the opinion section were also strongly or moderately correlated with the questions in the confidence section.

A strong correlation was seen between participants' map reading confidence (Q10) and their map navigation confidence (Q12), $r = .80$, $p < .001$, indicating the two questions are highly related. Map reading confidence (Q10) was strongly correlated with participants' confidence in their sense of direction (Q11), $r = .63$, $p < .001$. Additionally, Q10 was positively correlated with whether participants were confident using the current map, $r = .52$, $p < .001$. This statistic was not surprising given the expected variability in responses for Q14 for the different test graphic types. The question asking participants if they felt they had a strong sense of direction (Q11) was strongly correlated with map navigation confidence (Q12), $r = .63$, $p < .001$. Also, the map navigation confidence question (Q12) was strongly correlated with participants who were confident using the current map (Q14), $r = .50$, $p < .001$. The two questions related to landmark descriptions, verbal (Q8) and written (Q9) directions were strongly correlated, $r = .60$, $p < .001$. Not surprisingly, the two questions related to sense of direction, if participants frequently get lost (Q6) and their confidence in their sense of direction (Q11) were strongly negatively correlated, $r = -.59$, $p < .001$ as well.

Moderately positive correlations were seen for Question 5 asking participants if they use maps and three of the five confidence questions: map reading confidence, map navigation confidence, current map confidence. Whether participants agreed they used maps more often (Q5) showed a moderate positive correlation with their greater confidence for reading maps (Q10), r = .49, $p < .001$; as well as their confidence navigating with maps (Q12), r = .46, $p < .001$. There was also a moderate correlation between Q5 and participants' confidence using the current map (Q14), r = .31, $p < .001$. This result was not surprising given the image group would be less likely to be confident using the test graphic. Also, a moderate correlation was seen between participants who were confident reading maps (Q10) and if they were confident using Internet mapping programs, r = .39, $p < .001$.

Moderately negative correlations were seen for Question 6 asking participants if they easily get lost in unfamiliar cities with map navigation confidence (Q12) and map reading confidence (Q10). Participants answered they get lost more often appeared to be less confident navigating with maps, $r = -.41$, $p < .001$, as well as less confident reading maps, r = .37, $p < .001$.

Weak negative correlations were seen between Q6 and the two questions related general spatial interaction such as Internet map usage (Q7) and use of written landmark descriptions (Q9), as well as Internet map confidence (Q13) and confidence using current test graphic (Q14). The moderately small negative correlation between participants who easily get lost in unfamiliar cities (Q6) and confidence using the current map (Q10) was seen, $r = -.22$, $p < .001$. The previous was a stronger inverse correlation compared to the questions related to Internet map usage; Q6 and Q7, $r = -.13$, $p < .05$, and Q6 and Q13, r = .15, $p < .05$. An unexpected negatively weak correlation was see between Q6 and Q8, $r = -.15$, $p < .05$.

Weak correlations were detected between participants who frequently use maps (Q5) and tend to get lost in unfamiliar cities (Q6) as well as verbal landmark usage (Q8) and confidence using Internet mapping applications (Q13). Q5 and Q6 shows a small

TABLE 4.8. Experiment 2 Inter-item Correlation Scores for the Likert-scale Questions

Scale	1	2	3	4	5	6	7	8	9	10
Q5: Use maps?	—	$.16^{*}$	$.20^{**}$	.01	-.02	$.49^{**}$	$.25^{**}$	$.46^{**}$	$.24^{**}$	$.31^{**}$
Q6: *Inverse* Get lost?		—	$-.13^{*}$	-.06	$-.15^{*}$	$.37^{**}$	$.59^{**}$	$.41^{**}$	$.15^{*}$	$.22^{**}$
Q7: Use Internet mapping?			—	$.22^{**}$	.12	.09	.03	.08	$.49^{**}$	.11
Q8: Use verbal landmarks?				—	$.60^{**}$	.09	.11	.06	$.19^{**}$	.06
Q9: Use written landmarks?					—	.00	-.02	-.03	.08	-.10
Q10: Map reading confidence?						—	$.64^{**}$	$.80^{**}$	$.39^{**}$	$.52^{**}$
Q11: Sense of direction?							—	$.63^{**}$	$.41^{**}$	$.41^{**}$
Q12: Map navigation confident?								—	$.40^{**}$	$.50^{**}$
Q13: Internet mapping confident?									—	$.39^{**}$
Q14: Confident with current map?										—

$^{*}\ p < .05$

$^{**}\ p < .01$

positive correlation where r = .16, $p < .05$. Q8 and Q13 shows this effect as well, r = .19, $p < .001$. These weak correlations, as well as stronger correlations, will be addressed further in the Experiment 2 discussion. Experiment 2's correlation statistics can be viewed on *Table 4.8* on page 87.

4.3.2.3. Exploratory Factor Analysis

A post-hoc exploratory factor analysis was performed on the current Likert scale questions to detect any underlying latent variables. Three factors were identified with 67.32% of variance explained based on the initial eigenvalues and 58.72% based on a varimax rotation using a maximum-likelihood method (Costello and Osborne, 2005).

TABLE 4.9. Experiment 2 Factor Loadings for Exploratory Factor Analysis with Varimax Rotation of Likert-scale Questions

Scale	Confidence	Landmarks	Internet
Q5: Use maps?	**.46**	.04	.24
Q6: *Inverse* Get lost?	**.51**	-.10	-.12
Q7: Use Internet mapping?	-.02	.11	**.99**
Q8: Use verbal landmarks?	.05	**.61**	.15
Q9: Use written landmarks?	-.08	**1.00**	-.01
Q10: Map reading confidence?	**.88**	.09	.11
Q11: Sense of direction?	**.75**	.04	.04
Q12: Map navigation confident?	**.88**	.05	.13
Q13: Internet mapping confident?	**.41**	.12	**.52**
Q14: Confident with current map?	**.56**	-.05	.15

Note: Factor loadings $>$ .40 are in boldface.

These results show relatively strong correlation between the Likert-scale questions. The three factors identified are confidence, landmark usage, and Internet usage, *Table 4.9* on page 88.

The factor identified with confidence was strongly correlated to the five questions in the Likert confidence group identified in the initial reliability analysis (Q10 through Q14). An additional two questions from the Likert-scale general use group were the question asking participants if they used maps (Q5) and whether they usually get lost in unfamiliar cities (Q6). The majority of these questions strongly loaded on this factor with the strongest related to map reading confidence r = .88) and map navigation confidence (r = .88). The question related to Internet mapping confidence (Q13) loaded equally on confidence (r = .41) and Internet mapping (r = .52).

Not surprisingly the two questions related to landmark usage, Q8 and Q9, loaded strongly on the second factor identified as landmark usage. Curiously, the written landmark usage loaded strongly (r = 1.00); whereas verbal landmark usage (r = .61) loaded weakly on Internet mapping (r = .15) and less so on confidence (r = .05).

Unsurprisingly, the questions associated with Internet mapping use (Q7) and Internet mapping confidence (Q13) loaded on the third factor Internet Mapping. Q7 loaded strongly (r = .99) and Q13 (r = .52) loaded on two factors as stated previously. But surprisingly, the map use question (Q5) loaded weakly on this factor (r = .24).

4.3.3. Landmark Usage Statistical Analysis

Descriptive statistics for measures of central tendency and dispersion were performed on participants' description of landmarks for the route description section of the test. A total of 117 male and 138 female scores were used in the analysis of variance. There were 31 males and 35 females in the image group (test graphic 1), 27 males and 33 females in the map overlay without landmark labels group (test graphic 2), 33 males and 34 females in the map overlay with landmark labels group (test graphic 3), and 26 males and 36 females in the map group (test graphic 4), *Table 4.10* on page 90.

Descriptive means and standard deviations comparing sex based on test graphic type were calculated and the differences between the sexes did not appear to differ by too much. Males (M = 2.77, SD = 2.06) and females (M = 2.26, SD = 2.13) described a comparable number of landmarks for the test graphic 1. A similar result was seen for test graphic 2 where males described slightly more landmarks (M = 0.59, SD = 1.34) than females (M = 0.33, SD = 0.78). Contrast the above result with the map overlay with landmark labels (test graphic 3) where there appeared to be males (M = 1.82, SD = 1.76) described less landmarks than females (M = 2.65, SD = 1.91). The final test graphic

TABLE 4.10. Experiment 2 Sex by Map Type Cell Counts

Sex	Graphic 1	Graphic 2	Graphic 3	Graphic 4	Totals
Male	31	27	33	26	117
Female	35	33	34	36	138
Totals	66	60	67	62	255

group showed not much difference in landmark descriptions comparing males (M = 3.00, SD = 1.88) and females (M = 2.97, SD = 1.91). In fact, the greatest difference in landmark usage appears to be when comparing the test graphic groups where the map overlay without landmark labels (test graphic 2) had less subjects describing landmarks compared to the other three test graphic groups, see *Figure 4.10* on page 91.

A graphic comparison showing the differences in total number of landmarks described for each test graphic can be seen in *Figure 4.11* on page 92, where more landmarks were described in the image, map overlay with landmark labels, and map test graphics compared to the map overlay without landmark labels. Comparisons between male and female total landmark usage show similar counts between males and females in the image test graphic for the first landmark (males = 9, females = 9). More landmarks were described in the map overlay with landmark labels for the first landmark (males = 17, females = 16) and in the map test graphic (males = 17, females = 18) than used in the previous test graphic. Contrast the previous with the map overlay without landmark label test graphic where far less participants described the first landmark (males = 4, females = 3). Similar results were seen comparing total landmarks described for the map overlay without landmark labels with the other three test graphics.

Total landmarks described for the last landmark for the image test graphic showed slightly more males (15) described the landmark more than the 13 females. Less males

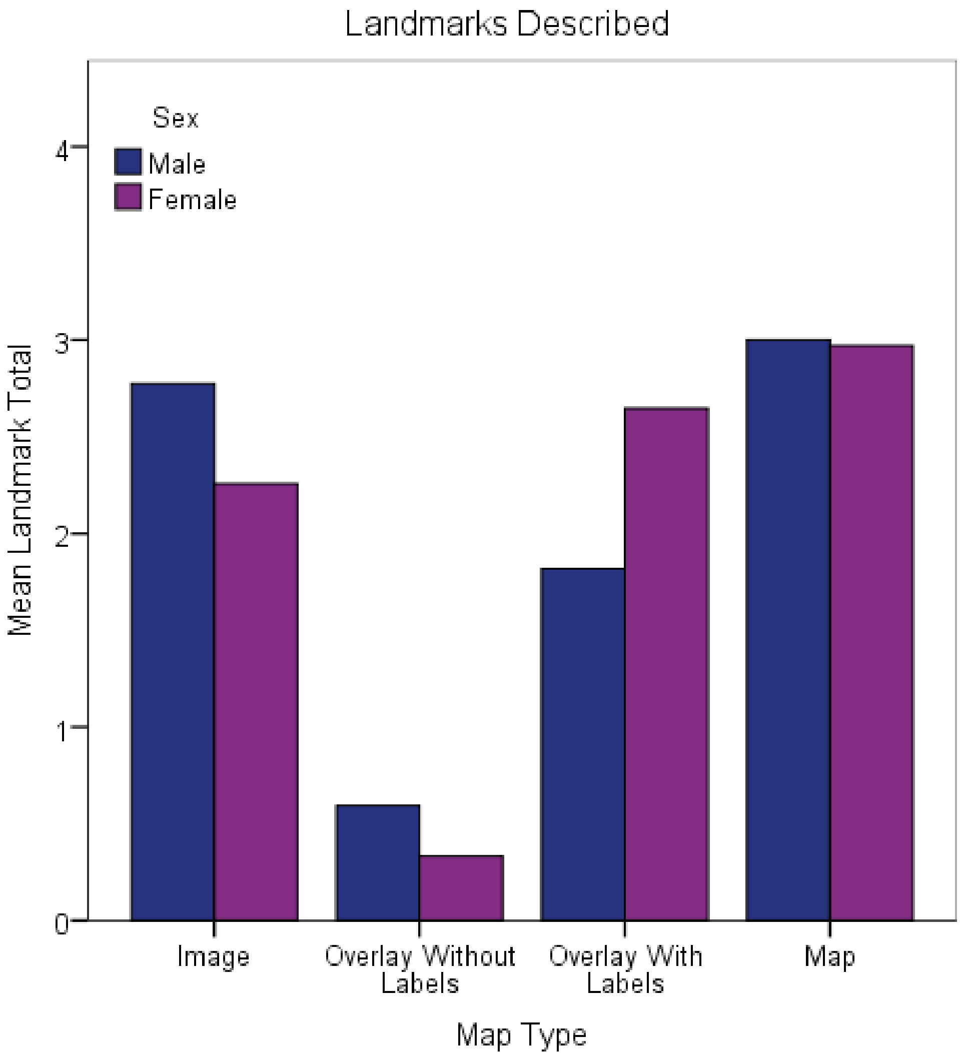
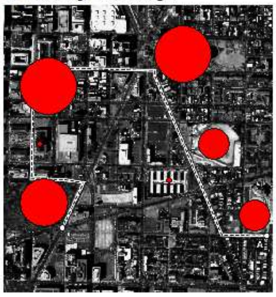


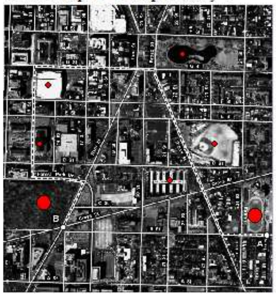
FIGURE 4.10. Experiment 2 mean landmark usage grouped by sex.

a. Test Graphic 1: Image



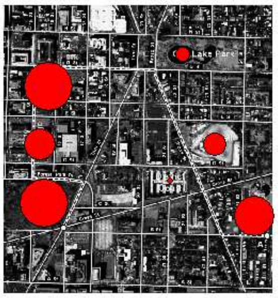
Feature	M	F	Total
High School	9	9	18
District Court	0	1	1
Baseball Field	8	9	17
City Lake Park	17	15	32
Arts Center	16	19	34
City College	0	0	0
Forest Park	15	13	28
Totals:	65	66	130

b. Test Graphic 2: Map Overlay 1



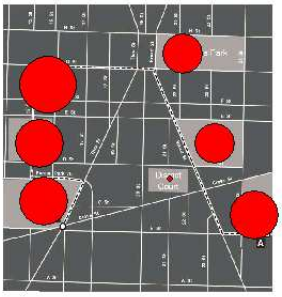
Feature	M	F	Total
High School	4	3	7
District Court	0	0	0
Baseball Field	2	1	3
City Lake Park	1	2	3
Arts Center	3	1	4
City College	0	0	0
Forest Park	3	4	7
Totals:	13	11	24

c. Test Graphic 3: Map Overlay 2



Feature	M	F	Total
High School	17	16	23
District Court	0	0	0
Baseball Field	5	6	11
City Lake Park	4	5	9
Arts Center	11	17	28
City College	8	12	20
Forest Park	11	19	30
Totals:	56	75	121

d. Test Graphic 4: Map



Feature	M	F	Total
High School	12	18	30
District Court	2	2	4
Baseball Field	10	13	23
City Lake Park	8	15	23
Arts Center	14	21	35
City College	13	17	30
Forest Park	13	17	30
Totals:	72	103	175

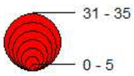


FIGURE 4.11. Experiment 2 landmark descriptions results for each test graphic type. Circle sizes represent total counts for each landmark. Tables display male (M) and female (F) description comparisons plus total counts.

described the last landmark in the map overlay with landmark labels (11) and map (13) compared to 19 females in the former test graphic group map and 17 females in the latter group. The map overlay without labels showed less counts where only three males and four females described the last landmark.

A planned two-factor between-subjects analysis of variance (ANOVA) was performed, exactly like Experiment 1, with the independent variables sex as a fixed factor and map type as a random factor. The average number of landmarks was the dependent variable described by participants. A statistically significant at the α = .05-level was found for the main effect map type, F(3, 2032) = 12.96, p = .03, partial η^2 = .93. However, the ANOVA was planned for a stricter α = .01 level, and thus was not significant at the higher level (see Experiment 2 Discussion for more explanation). There was no significant main effect for sex, F(1, 2032) = 0.00, p = .99, partial η^2 = .00; and no significant interaction between map type and sex, F(3, 2032) = 1.73, p = .16, partial η^2 = .02.

Planned simple comparisons between the average number of landmarks described per map type were conducted using a Bonferroni adjustment. There was a statistically significant result comparing Test Graphic 2 (map overlay without landmark labels) results with the three other test graphics. Participants described more landmarks descriptions in Test Graphic 1 (image) compared to Test Graphic 2 (image overlay without labels), F(3, 254) = 2.05, $p <$ .001, 99% CI [1.02, 3.08]. Similar results were seen comparing the two map overlays where participants described less landmarks in the test graphic without labels compared to the test graphic with labels, F(3, 254) = -1.79, $p <$ .001, 99% CI [-2.81, $-.77$]; less participants described landmarks in the image overlay without landmarks (Test Graphic 2) compared to participants using the map, F(3,254) = -2.53, $p <$ .001, 99% CI [-3.58, -1.49].

The analytic comparison between the image (Test Graphic 1) and the map (Test Graphic 2) showed no statistically significant difference between landmark descriptions, $F(3, 254) = -0.48$, $p = .79$, 95% CI $[-1.50, 0.53]$. Non-significant results were seen between the map overlay with labels (Test Graphic 3) and the map (Test Graphic 4) as well, $F(3, 254) = .74$, $p = .12$, 99% CI $[-.27, 1.76]$, where both test graphics had the landmarks labeled, *Figure 4.12* on page 95.

Recall that the literature has stated that females tend to use more landmarks than males when describing routes. A landmark score was tabulated from the two Likert-scale questions asking participants whether they use landmarks either using verbal or written means. Mean scores ($M = 7.04$, $SD = 2.15$) for the 113 males who responded did not differ much from the 134 females ($M = 7.10$, $SD = 2.14$). No statistically significant result was seen between males and females, $t(245) = -.22$, $p = .83$, (2-tailed). A graphic comparison can be seen on *Figure 4.13* on page 96 to show the sexes do not differ much in using landmarks for describing routes.

4.3.4. Spatial Knowledge Statistical Analysis

Descriptive statistics for environmental descriptors were compiled the same as Experiment 1. The research hypotheses were the same as the first experiment where males would use the standard distance estimators and cardinal direction turns when describing the test route; whereas, females would use non-standard distance estimators and left/right turns.

Males ($M = 0.80$, $SD = 1.63$) and females ($M = 0.79$, $SD = 1.50$) did not differ when using the standard units estimators, $t(253) = 0.07$, $p = .95$ (two-tailed), *Figure 4.14* on page 98. However, there was a statistically significant result, $t(253) = 2.49$, $p = .01$ (two-tailed), when comparing males ($M = 2.57$, $SD = 3.51$) and females ($M = 1.64$,

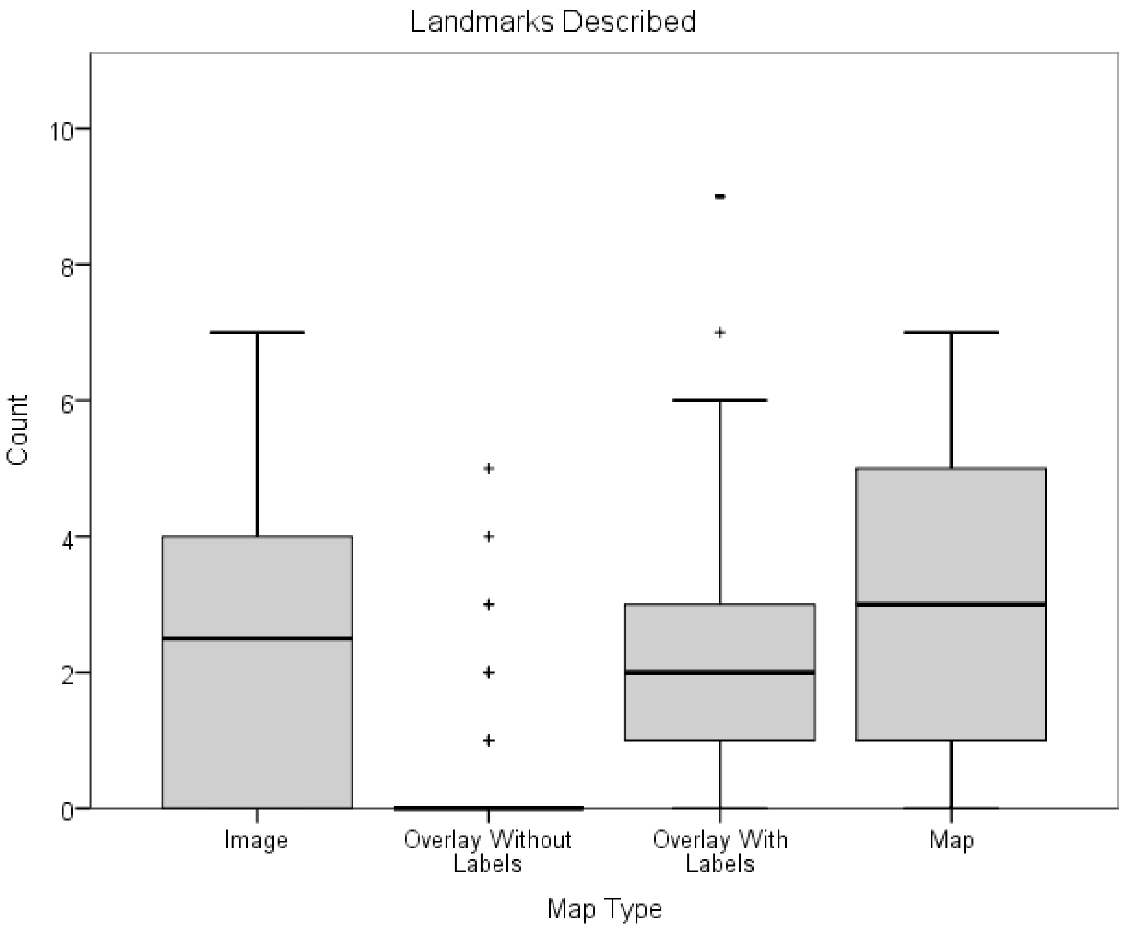


FIGURE 4.12. Experiment 2 mean landmark usage analytic comparisons showing means and ranges.

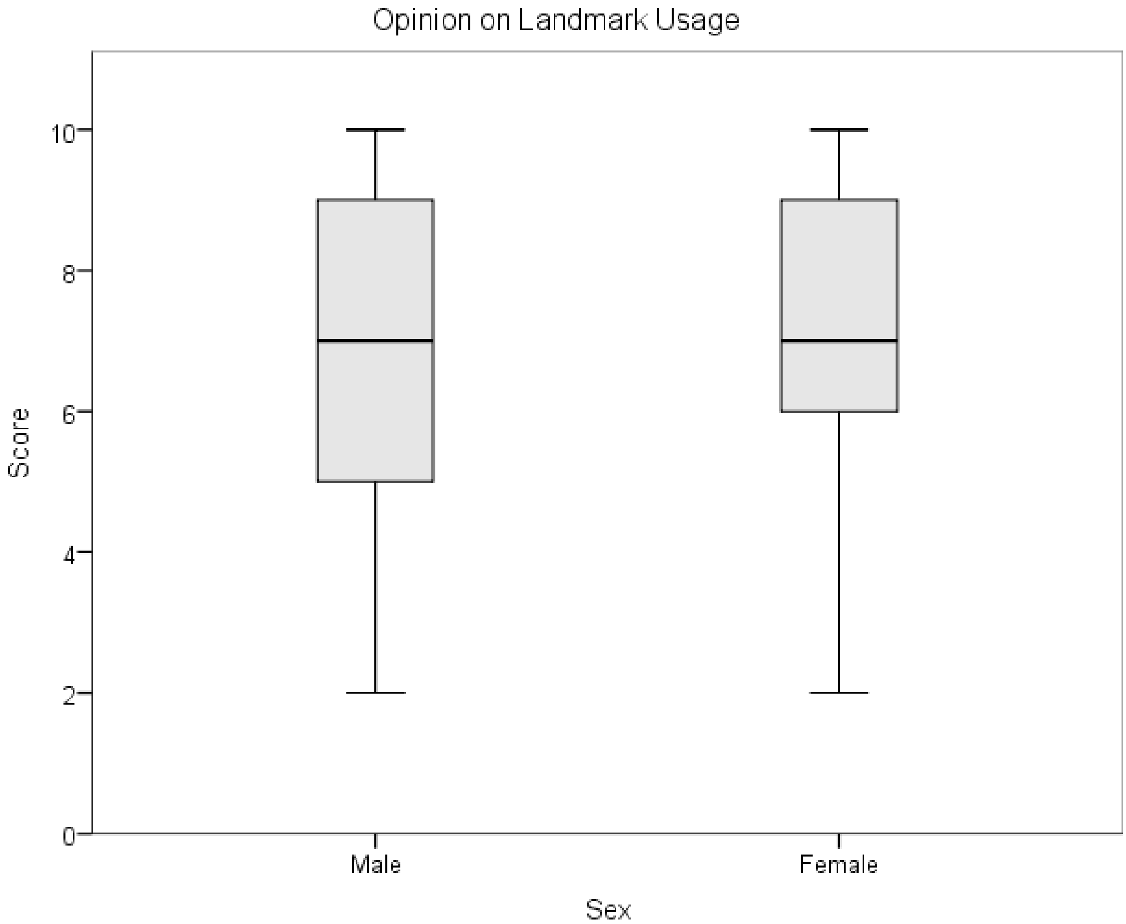


FIGURE 4.13. Experiment 2 landmark score comparing the sexes based on the two Likert-scale questions on using landmarks either verbal or written instruction.

SD = 2.42) using cardinal directions, *Figure 4.15* on page 99. But there was no statistically significant difference between males (M = 5.15, SD = 1.32) and females (M = 5.33, SD = 1.43) when using left/right turns, $t(252) = -1.05$, p = .29 (two-tailed); or when males (M = 1.11, SD = 1.73) and females (M = 0.80, SD = 1.37) used non-standard distance estimators such as intersections and blocks, $t(253) = 1.61$, p = .11 (two-tailed). Refer to *Figure 4.16* on page 100 for a graphic comparison between males and females usage of left/right turns, and *Figure 4.17* on page 101 for non-standard distance usage.

A planned ANOVA statistical analysis was designed where the two independent variables were sex and map type and the dependent variable was spatial knowledge with three levels. The hypothesis was more males would describe the routes using survey-knowledge descriptors regardless of map type. Conversely, more females would use more route-knowledge descriptors than males regardless of map type. Descriptive statistics were generated the same as Experiment 1 to determine if there was any validity to the general concept that males and females use different spatial descriptors when describing a route.

The majority (65%) of the 255 participants used a mixed method for describing the routes where slightly more females (88) used this method than males (80). For the participants who used primarily route-knowledge descriptors, more females (48) than males (37) used this method. No males, but two females, used survey-knowledge for their route descriptions, *Figure 4.18* on page 103.

Descriptive statistics for spatial knowledge based on map type were generated where the majority of participants used mixed methods for all test graphics compared to the route- or survey-knowledge method. The only test graphic where all three spatial knowledge types were used was in the image group. The majority of participants (53 out

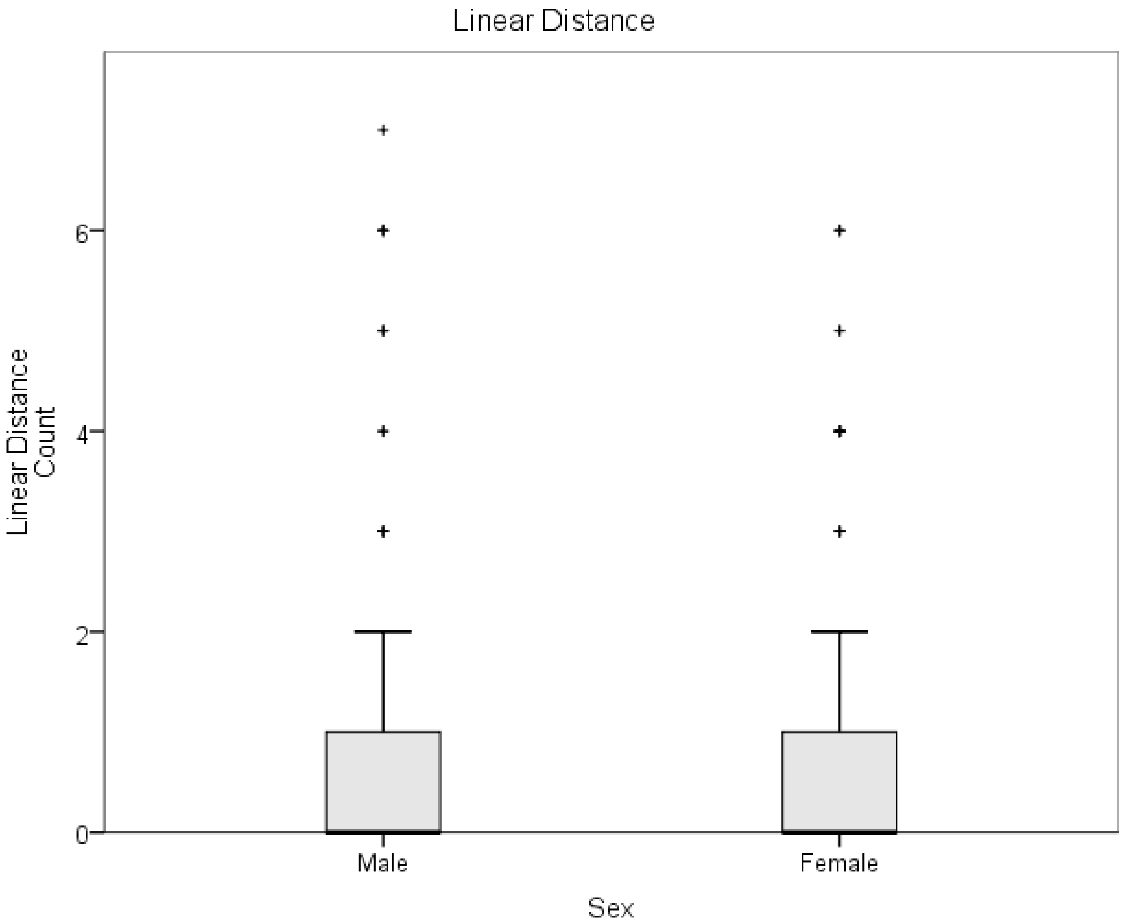


FIGURE 4.14. Experiment 2 standard distance usage based on sex.

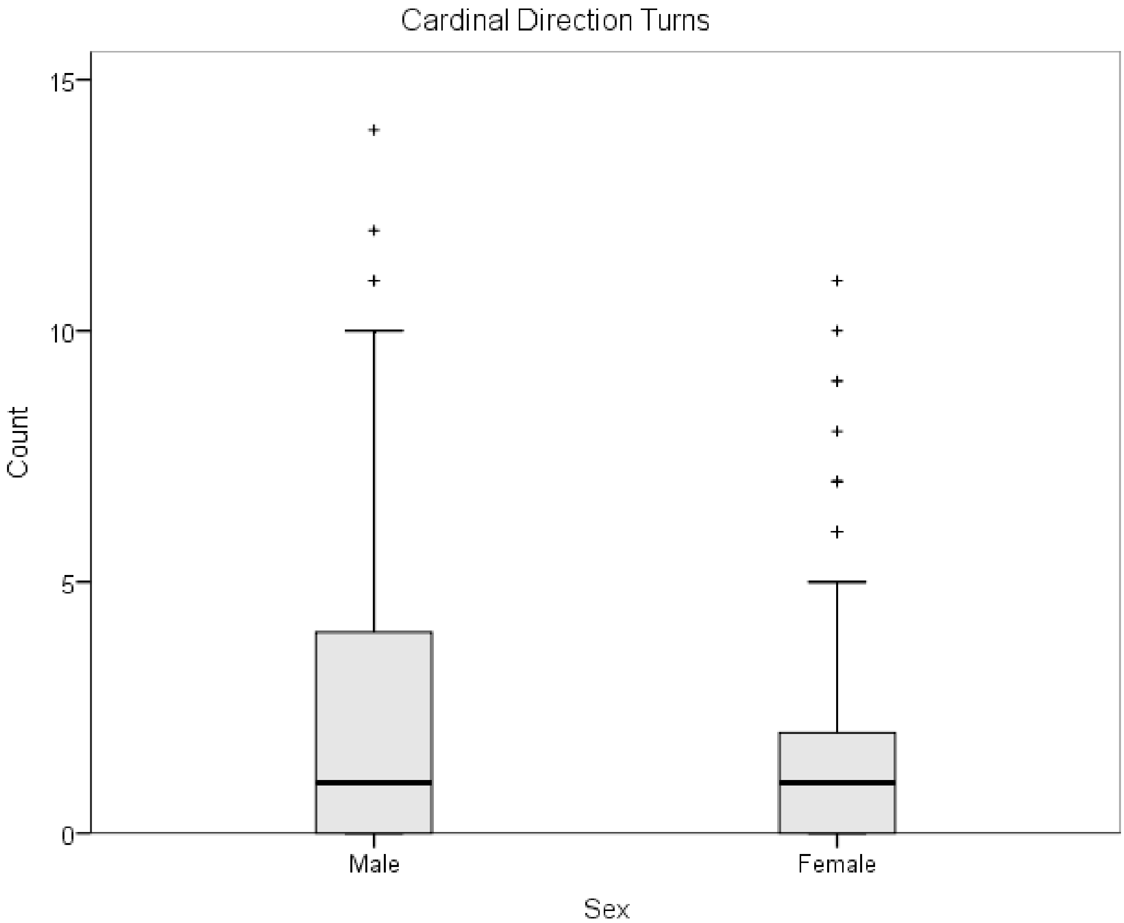


FIGURE 4.15. Experiment 2 cardinal direction turn usage based on sex.

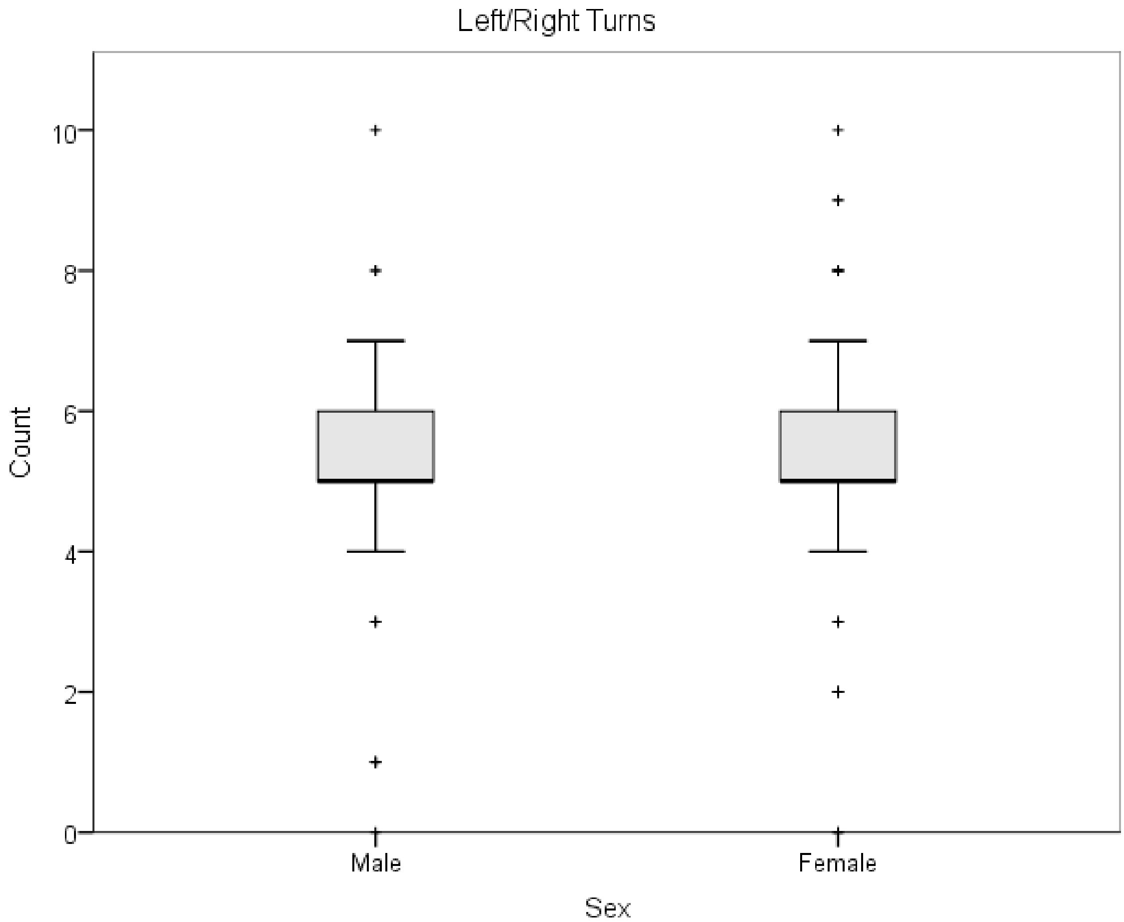


FIGURE 4.16. Experiment 2 left/right turn usage based on sex.

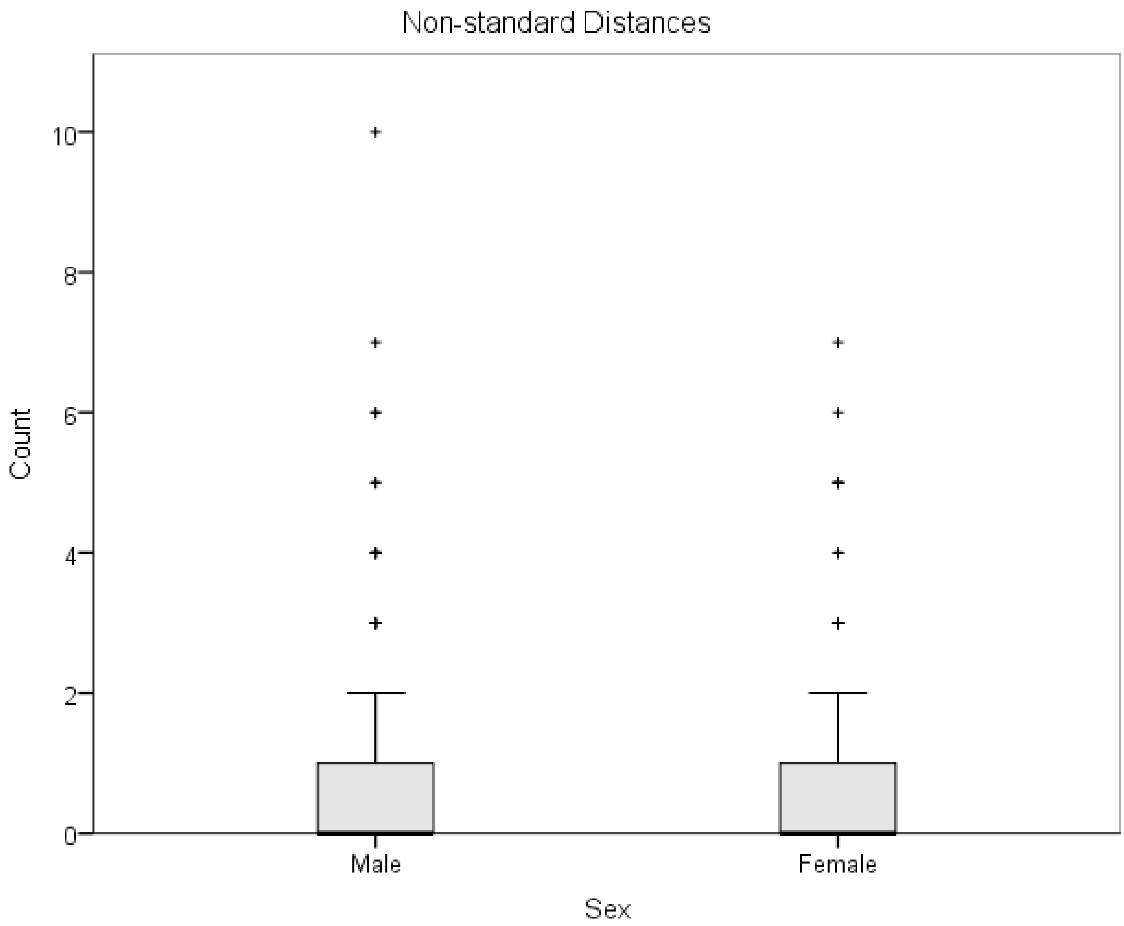


FIGURE 4.17. Experiment 2 non-standard distance usage based on sex.

of 66) used the mixed method, whereas 11 used the route-knowledge method. No males, but the two females mentioned above, used survey-knowledge to describe the route for the image test graphic.

The were no statistically significant results between the main effects nor the interactions regarding spatial knowledge descriptors. There was no statistically significant difference between males and females, $F(1{,}508) = 1.52$, $p = .31$, partial $\eta^2 = .34$; nor between map type, $F(3{,}508) = 4.43$, $p = .13$, partial $\eta^2 = .82$; nor an interaction between sex and map type, $F(3{,}508) = 0.54$, $p = .66$, partial $\eta^2 = .01$.

4.3.4.1. Distance and Direction Errors Statistical Analysis

Previous research literature states females tend to be more error-prone when it comes to estimating distances and directions. Distance estimator errors and directional errors for each segment of the route, minus segment 3, were tabulated from each participant's route description to produce a total error score. The research hypothesis was that more females than males would have higher error scores regardless of map type. An ANOVA where the independent variables were sex and map type, and the dependent variable was the error score was conducted.

Approximately 42% of participants (107 out of 255) did not commit any distance or direction errors across all map test graphic. More females (60) than males (47) did not have any errors. However, tabulations for multiple total errors showed slightly more females (70) committed between one and four errors compared to 66 males. Also, more females (8) committed between five to nine errors compared to only four males that committed five to six errors. In conclusion, more females committed no errors compared to males, yet more females also committed higher number of errors compared to males.

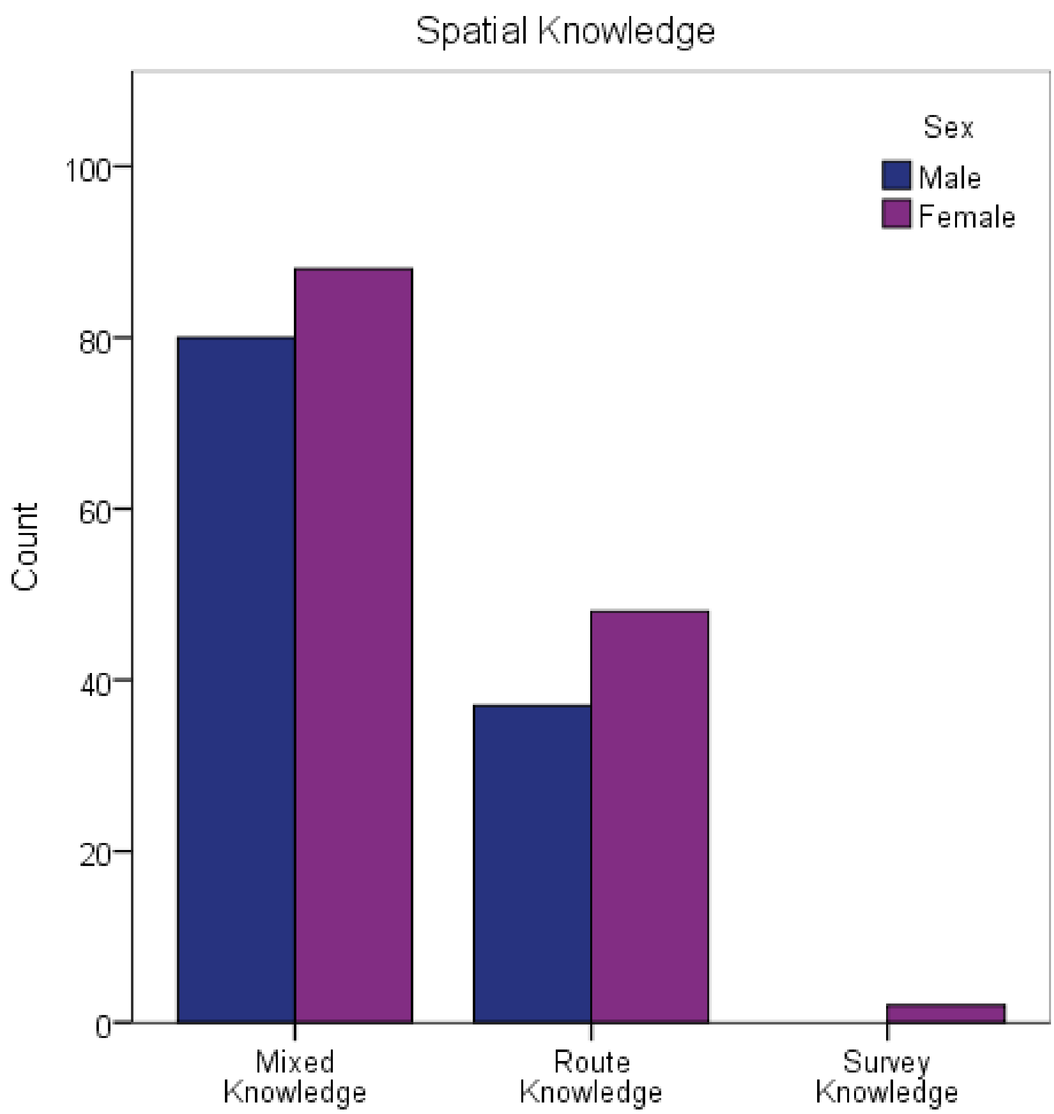


FIGURE 4.18. Experiment 2 spatial knowledge type grouped by sex.

Of the 42% of participants that did not commit any errors based on map graphic, more participants (34) committed no errors in the map graphic group compared to the map overlay without labels group (31), and the map overlay with labels group (29); whereas, the image group had the least number of participants (13) committing errors. The test map graphic that had the highest number or errors committed was the image group where 53 committed between one and seven errors. Contrast the high error rate from the image group with the 38 in the map overlay with labels group where one to five errors were committed. The map overlay without labels and map were comparable in error rates where 29 and 28 errors were committed, respectively (See *Figure 4.19* on page 105 for a graphic comparison grouped by test map graphics and sex). Curiously, more total errors, between one and nine, were committed in the map overlay without labels group compared to only a maximum of five errors in the map group. In conclusion, the image test graphic had the highest number of participants committing some sort of distance or direction error.

The results of the ANOVA showed no statistically significant results between sex and map type or any interaction between the two factors. There was no statistically significant difference between males and females, $F(1,508) = 0.19$, $p = .69$, partial $\eta^2 = .06$; nor between map type, $F(3,508) = 6.26$, $p = .08$, partial $\eta^2 = .86$; nor an interaction between sex and map type, $F(3,508) = 1.54$, $p = .21$, partial $\eta^2 = .02$, *Figure 4.20* on page 106.

4.3.5. Confidence Statistical Analysis

Given the above results showed no statistically significant difference between males and females when it comes to distance and direction errors, the next analysis addressed whether females tend to be less confident than males in their spatial awareness. Much

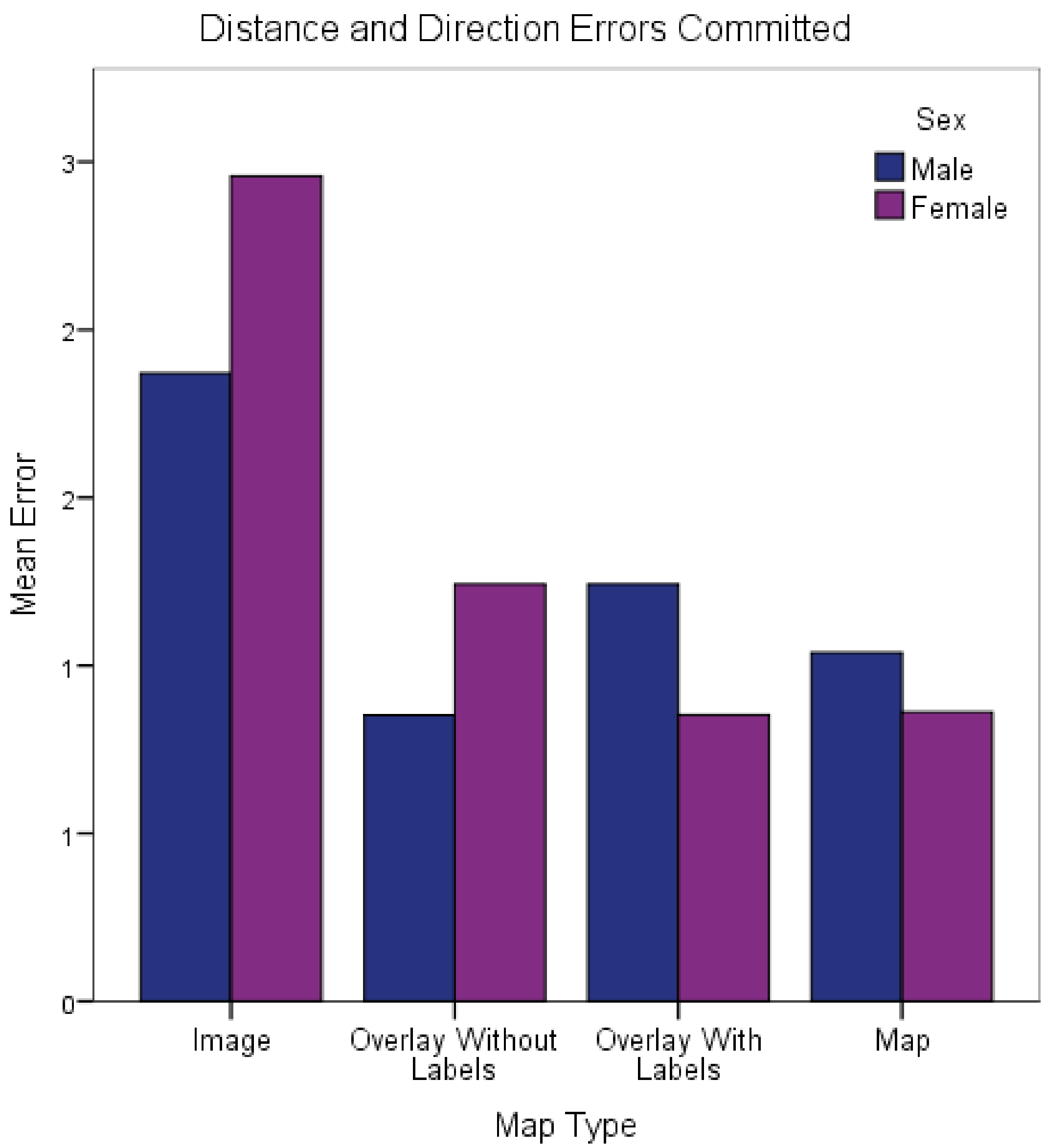


FIGURE 4.19. Experiment 2 total distance and direction errors committed based on map type grouped by sex.

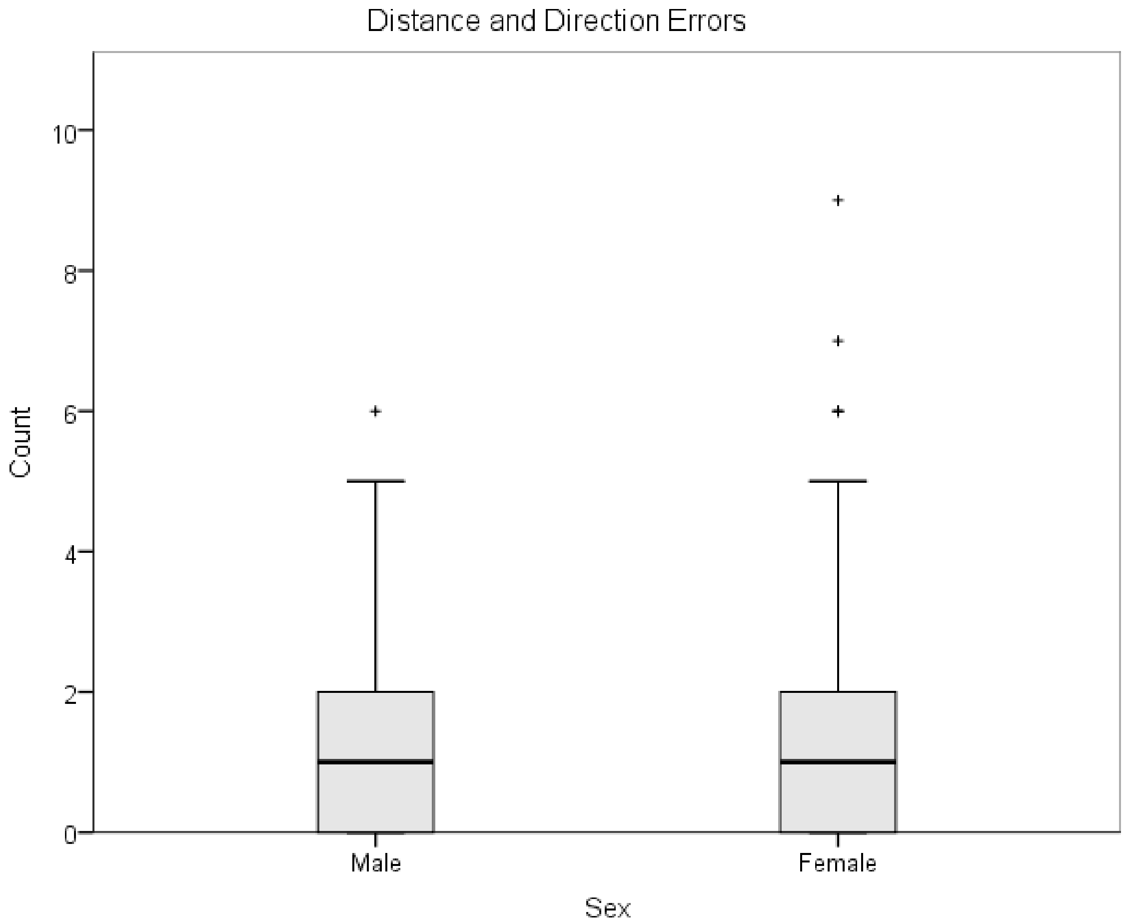


FIGURE 4.20. Experiment 2 total distance and direction errors committed based on sex showing means and ranges.

literature has addressed this issue as well where males tend to be more confident than females. A Student's *t*-test was conducted where the dependent variable was the total confidence scores tabulated from the confidence Likert-scale questions. The research hypothesis was that there would be a statistically significant difference between males and females where males would show higher confidence regardless of map type. Males, as predicted, scored higher in confidence scores (M = 19.54, SD = 4.42) and statistically significantly more confident, t(250) = 2.55, p = .01 (2-tailed) than females (M = 18.14, SD = 4.27), *Figure 4.21* on page 108.

A further question arose whether map type would determine if participants would be confident regardless of their sex. The research hypothesis was that the image would be the most difficult test graphic. Recall from above that more distance and direction errors were committed in the image group compared to the other three test graphic groups. The current ANOVA had the same independent variables of sex and map type but the dependent variable was the Likert-scale question asking how confident were participants using the current map. The research hypothesis was that map type would influence the confidence score, not sex. Analytic comparisons would predict less confidence in the image group compared to the other three test graphics.

Descriptive statistics showed the image test graphic group were less confident (M = 2.88, SD = 1.17) than the other three groups. Participants in the map overlay with labels group were the most confident (M = 4.30, SD = 0.76) as well as the map overlay without labels group (M = 4.27, SD = 0.88). The map group were similarly confident to the above two groups (M = 4.13, SD = 1.15) but with greater variability in their responses, *Figure 4.22* on page 109.

The omnibus analysis showed a statistically significant result for the main effect of map type, F(3,508) = 55.78, $p < .01$, partial η^2 = .98. There was no statistically

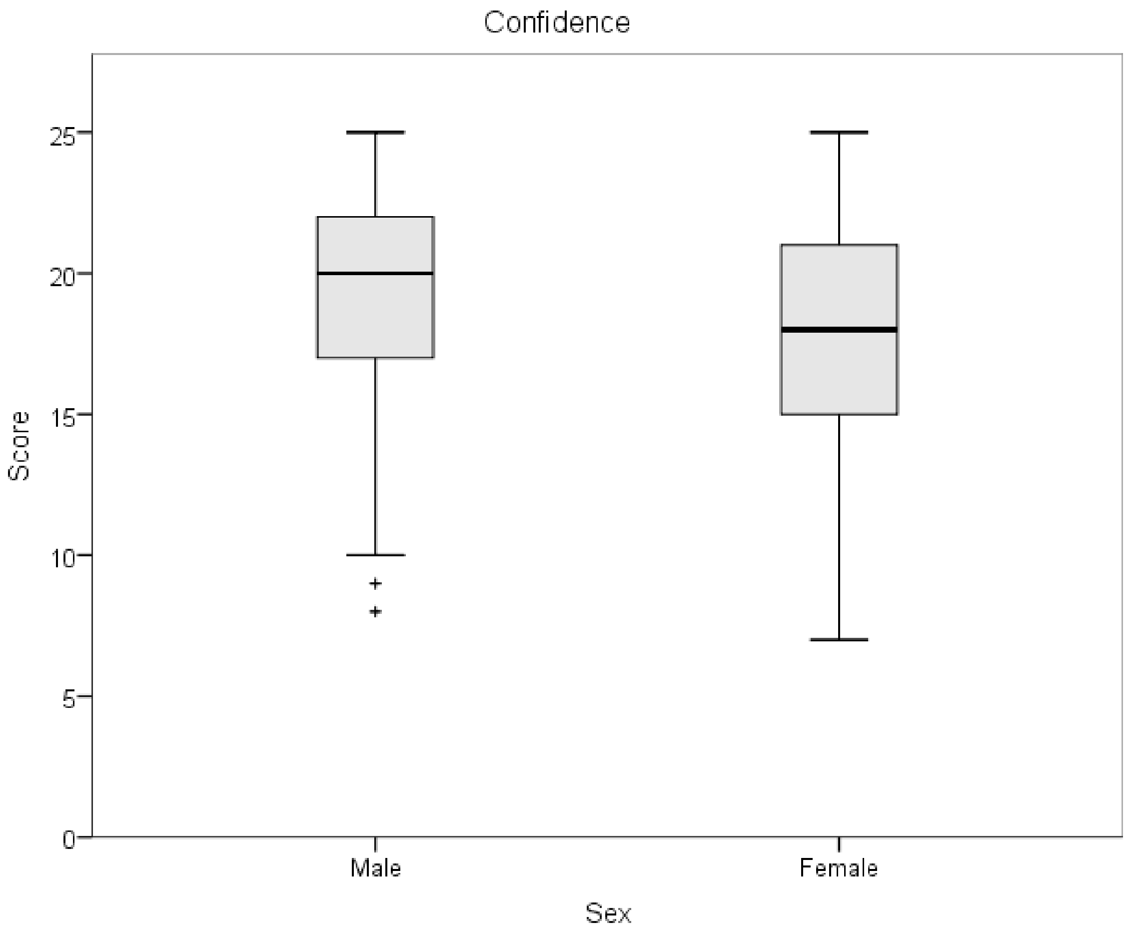


FIGURE 4.21. Experiment 2 confidence score based on Likert-scale confidence questions.

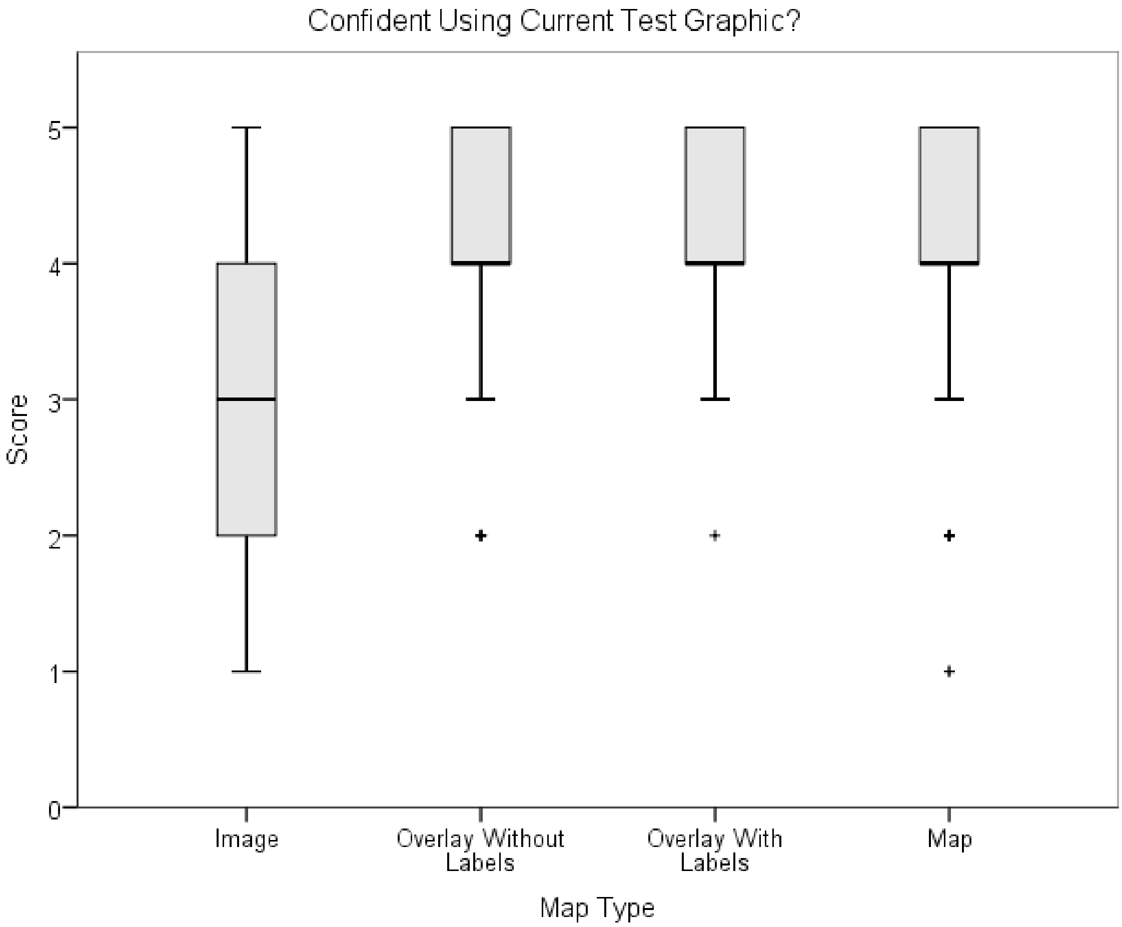


FIGURE 4.22. Experiment 2 confidence using current test graphic score (Q14) grouped by map type showing means and ranges.

significant difference between sex at the .01 level, F(1,508) = 10.26, p = .05, partial η^2 = .77. There was no statistically significant interaction between sex and map type, F(3,508) = 0.56, p = .64, partial η^2 = .01.

Post-hoc unplanned comparisons using the Dunnett test (Keppel et al., 1992) was conducted. Means between the image group compared to the three other test graphic groups were statistically significant than the mean for the second test graphic group, F(3, 254) = -1.39, $p < .01$, 99% CI [-1.99, -0.79]; the third test graphic group F(3, 254) = -1.42, $p < .01$, 99% CI [-1.98, -0.87]; and the last group F(3, 254) = -1.25, $p < .01$, 99% CI [-1.90, -0.60].

4.4. Experiment 2 Discussion

4.4.1. Test Instrument Redesign

One slight change in the route description instructions where participants write their responses included bullets in order to key participants to write each block of instructions on one line. Another reason was to try to force participants to think of writing down each block of instruction for each segment without deliberately including any indication of seriation in order to facilitate data transcription for Experiment 2. Problems were encountered in Experiment 1 when transcription commenced where it was difficult to determine where there were distinct blocks of instruction identified by route segments. Many of the route descriptions in the first experiment were written as free-flowing narratives. However, it became apparent that many test participants for the current experiment disregarded the bullets all together and wrote descriptions for each route segment using as many lines as needed. In fact 95% of the 255 participants did not use any form of seriation in their route descriptions.

4.4.2. Test Administration

Experiment 2 was designed specifically to address the shortcomings of the pilot study of not being a designed experiment. Prior to test administration for the current experiment, a power analysis was conducted for a planned ANOVA analysis. The power analysis results indicated that 20 participants in each of the test groups would be sufficient to meet the statistical power of .80 and α = .01 level. However, the final tally was 285 participants who went through the experiment and not the 160 originally planned. The major problem was the uneven male-to-female ratios from each test session.

The test pool for the current experiment came from the SJSU Psychology Department test subject pool. The official policy in the department is that all experiments must be advertised, and all students who wish to participate are allowed to do so. Given the test participation pool was from the lower division Psychology classes, more females participated than males. Personal conversations between myself and Drs. Laraway and Snycerski revealed that the majority of undergraduate students in the Psychology department are females, especially in the introductory courses; thus the overwhelming number of female participants in the early test sessions.

More sessions were needed in order to recruit more males, so more test sessions were conducted. However, given department policy that no student should be refused admission to a session, even though the criteria stated males only, female students were allowed to participate in latter test sessions. Thus the number for each cell increased sometimes by 10 from the original target number. The results were that the male-to-female ratio was not 1:1 for all sessions. The map overlay groups were the closest to even numbers with 27:33 for the test graphic 2 group, and 33:34 for the test graphic 3 group. The test graphic 1 group had 31:35, whereas, the last graphic group had the most lopsided ratio of 26:36. Recall that a total of 285 students participated but after reviewing route descriptions, 269 were usable before analyzing the route descriptions. Unfortunately the nine males out of a total of 14 described had to be eliminated after initial analysis of the route descriptions.

Six of the males from the pool did not follow the instructions according to test administration instructions and had to be eliminated from the statistical pool. One of those six route description written by a male was incomprehensible compared to four female's route descriptions. Of the four participant's route descriptions that were eliminated because they were backward, from point B to point A, three of those were from males.

Because Psychology Department test participants are required to participate in experiments in order to get partial credit in their courses and because most experiments are anonymous, there is no way a test administrator can guarantee each participant takes the experiment seriously. Unfortunately, there is no way for the researcher to determine with certainty whether there was true incomprehension on the part of the test participant or because the subject did not give the experiment serious consideration. This experiment was designed to investigate the differences between males and females at a spatial task. The reality was that more males' route descriptions had to be eliminated for the reasons stated above and thus the unbalanced cell counts.

4.4.3. Calculating an Experience Score

Two of the questions in the demographic questionnaire were supposed to capture the level of experience with map using the criteria number of high school or college-level courses participants took in prior years. An expectation was that these questions could be used as proxies for experience rather adding an additional bank of questions. A rule of thumb in research design states that the Law of Parsimony comes into play in order to not fatigue the test subject. The experimental design was supposed to be short in duration with a maximum of 20 minutes total time to do the experiment. During the design phase more effort was put in to ensure capture of information regarding general map use and spatial confidence but not map experience. Unfortunately this resulted in a floor effect where there was not enough data to calculate an experience score.

The experience score generated from the two Likert-scale questions showed no statistically significant difference between the sexes. Yet when taking each Likert question in isolation one can see there is a difference between males and females in map use and Internet map use. For the purposes of this experiment, it would have been better if the research design included more questions related to experience in order to perform quantitative analysis related to test map graphics, confidence, and errors.

4.4.4. Likert-Scale Statistical Analysis Design

The overall reliability of .76 for the Likert questions was not as robust as the expected value of .80. Given the general map use questions had lower reliability than the questions in the confidence section, this shows the questions in the first section had less concepts in common compared to the second section. If the experiment were to be re-run again, then there should be an opportunity to investigate to add more Likert-scales questions directly related to experience in order to capture an experience factor for further statistical analysis.

4.5. General Discussion

The following paragraphs will address the two research questions and also address the findings in the context of reliability and validity of the methods used for the two experiments.

4.5.1. Research Question 1

Does map type mitigate route description strategy? According to the findings of the ANOVA performed on both experiments, map type does influence whether landmarks will be used for describing a route. This contradicts the literature that states that females tend to use more landmarks than males. The results of both experiments show that using different test graphics had different outcomes. The image test groups in both experimental conditions show many landmarks were described. The map overlay without landmarks in both experiments showed a general absence of landmark descriptions in all groups, and the map test groups showed landmarks being described more than the other map graphic types. The map overlay with landmarks test graphic showed comparable numbers of landmarks described to the map test groups. Graphic comparisons, and not statistically significant differences, revealed females and males will describe more or fewer landmarks with different test graphics.

More males than females described landmarks in the image graphic groups for both experiments. The number of landmarks described in the map overlay without labels (Test Graphic 2 in both experiments) was similar for both sexes where there was a minimal number of landmarks described. The test groups that used the graphics that had the landmarks labeled, Test Graphic 3 in Experiment 1 and Test Graphics 3 and 4 in Experiment 2, showed more females described the landmarks. When reviewing the results for the map alone the difference agrees with the literature—females do tend to use more landmarks when describing a route. However, when taken in totality, different map types can influence if landmarks are described.

So why the contradiction? Perhaps the reason more males described more landmarks in the image test groups was that they were conducting aerial photography interpretation—being remote sensors—using any cues they could to describe the route with somewhat accurate results. Females described more landmarks when they were labeled. Perhaps this is from females' general lack of confidence, or possibly lack of spatial ability, when performing spatial tasks. If the feature is labeled and there is no ambiguity about its identification, then females will describe the feature.

Another avenue of investigation is to see which of the landmarks were described in each of the test graphics. The literature states that landmarks will be described more often at critical junctions, such as the start, end, and locations at a change in direction (Couclelis et al., 1987; Michon and Denis, 2001). This is evidenced by looking at the number of landmarks described in the map overlay without labels group where the start and end landmarks were described more often compared to the other landmarks. The other landmarks, such as at the change-in-direction intersections. This results can also be seen in the landmark description results based on map type as well.

The along-path test landmarks that were not at critical junctions were described the least unless they were salient to the test subject. For example, the *Baseball Field* was purposely included to see if that obvious physical feature for Americans would be described. For the other along-path test landmarks, such as the *Courthouse/District Court* and *Hospital/City College*, there was hardly any mention of those features in the test maps that had the image base map. However, the opposite result occurred when those along-path features were labeled. More references to the above mentioned test landmarks were described as the route was coming to the end. Michon and Denis (2001) observed that towards the end of the route, "the frequency with which landmarks were mentioned increased in the vicinity of the arrival point" (p. 297). This is true when the landmarks are labeled.

A counter to Research Question 1 was if males and females differ using specific environmental descriptors as the literature states (Ward et al., 1986). The results from

Experiment 1 did not show any statistically significant differences between environmental descriptors related to survey knowledge using standard linear distances and cardinal directions, and route knowledge using non-standard distances and left/right turns. In fact the majority of participants used left/right turns describing the test route. Contrast that to results in Experiment 2 where males used more cardinal directions than females when describing the route. However, there were no statistically significant differences between the sexes when using linear and non-standard distances and left/right turns. The similar results where the majority of participants used left/right turns for both experiments could be explained by, perhaps, the ubiquity of Internet mapping applications that influenced participants choice of turn types. Prior research in Psychology relied on planimetric test maps that arguably did not appear to resemble typical navigation maps. The additional imagery and photomaps could have cued the participants the experiment was about Internet mapping applications.

What is curious is the statistically significant difference in Experiment 2 where males used cardinal directions. Recall the test pools for each experiment were college students from different universities, but more importantly, different college disciplines. Experiment 1's test pool came from a majority of students in Geography. Arguably the test pool was more experienced when using maps. Experiment 2's test pool was primarily from Psychology and Behavioral Sciences. Although Experiment 2's criteria, two questions on number of geography classes taken, for determining which participant had more experience with maps could not be used; the second experiment test pool was considered to be less experienced than the test pool for Experiment 1. Yet the results for using cardinal directions for route description agrees with the literature (Galea and Kimura, 1993; Ward et al., 1986).

Although Experiment 1 was exploratory and not a designed experiment; whereas, Experiment 2 was planned and added another test graphic, the results from the ANOVA had similar outcomes. Thus the experimental results were repeated. A caveat was that the stricter α = .01 criterion was not met for Experiment 2 where α = .03. If the critical value of α = .05 set as the same as Experiment 1, then yes, the results are statistically significant. But because Experiment 2 was designed to perform many statistical analyses, the criteria for failing to reject the null hypothesis for the omnibus analysis perhaps was set too strict.

The possibility of committing a Type II, retaining the null hypothesis when in fact the alternative hypothesis is correct, is a possibility for one can never be 100% certain. Experiment 2 was designed with controlling for potential errors (Keppel et al., 1992) where 1) sample size was increased for each cell to increase the mean square terms in the numerator and to increase the F-ratio; 2) another test graphic was added another to try to increase the size of the effects of the treatments; 3) the possibility of increasing experimental error was controlled by random assignment of the test packets and the selection of an anonymous subject pool where the possibility of reactivity was nil; and 4) designed for a more sensitive experimental design where Experiment 2 where the test protocol was streamlined (p. 195–196). In hind-sight the critical value of F was set too strict; whereas, most psychological research accepts the more common α = .05 level.

4.5.2. Research Question 2

Does sex confound confidence and accuracy in describing routes? The results from Experiment 2 show that there is no statistically significant difference between males and females when reviewing the calculated errors committed in distance estimation or directions. However, females tend to be less confident from their scores and this ties to the literature when confronted with the concept of “spatial anxiety” (Lawton, 1994). Females do appear to be less confident when it comes to performing spatial tasks. The larger question is whether females generally tend to be less confident, regardless of task, than males. That is a question that cannot be answered by the research described in this monograph.

Another issue was identifying the numbers of multiple errors for distance estimation and direction. A small percentage of females committed multiple direction errors. However, the direction error score was not sensitive to capture whether the direction error was based on left/right turns or cardinal directions. This is unfortunate where this information was not completely expected. If more direction errors were committed, then this could be a function of not enough exposure to basic geographic principles in elementary and secondary school education, or perhaps, male/female differences in spatial abilities. But what can be learned from this experiment is that there are avenues for teaching possibilities to nurture young females to become more confident and competent in spatial tasks.

4.5.3. Research Design

The intent of Experiment 1 was an exploratory examination to determine if different outcomes would be present in a simple task like describing a route using different map graphics. Although the experiment was not designed for a specific statistical analysis procedure, there were surprising initial results. Contrary to the literature, there were differences in landmark usage compared across the three map graphic types. Many questions arose whether the results were truly meaningful given the potential threats to validity such as reactivity and using a limited sample pool.

Experiment 2 was designed to see if the results could be duplicated but also extrapolate whether there were mitigating circumstances for such outcomes, such as whether participants usually use landmarks for route descriptions or if Internet mapping applications could influence the results. The results from Experiment 2 showed the same results that map type influences the use of landmark descriptions. This is an indication that test stimuli can influence the outcome of an experiment. The intent of the research was basic, and yet the results can have implications for future research in geographic teaching, map design, and Internet mapping applications.

4.5.4. Recommendations for Future Study

The results from the two experiments are preliminary in nature. What was not captured was an experience score and whether experience influences landmark usage across map types, spatial knowledge route description strategies, and error. An additional bank of questions in the Likert-scales section for similar to some of the questions designed by Hegarty, Richardson, Montello, Lovelace, and Subbiah (2002) would capture an experience score. Additional questions related to the above work, will also categorize participants' route description strategies prior to analyzing their route descriptions. If their natural route description strategies were influenced by the different map types, then research avenues can follow in different directions.

Landmark descriptions based on map type showed males tend to interpret the image test graphic more than females. This appears to show that males are willing to recognize, identify, and interpret environmental features than females. A recent trend in geographic education is to move away from basic aerial photographic interpretation and emphasize digital remote sensing techniques. But due to the ubiquity of satellite imagery used in on-line mapping applications as well as recent maps, perhaps air photo interpretation should be a fundamental skill to be taught in secondary and tertiary education.

A major concern to this researcher is the disturbing results regarding the outliers for direction errors. As stated above, females committed more multiple errors than males. Whether this is a function of spatial ability differences or education, has been addressed in the literature and is a contentious topic. Numerous test graphic maps were returned where the directional arrow had been changed to a compass rose where north, south, east, and west were indicated. The research group did not take in consideration that, perhaps, the majority of people do not memorize their cardinal directions. Thus issues in map design should be addressed as well. Because many test graphics in Experiment 2 came back with hand-written compass roses, it is advisable that map designers continue to include at least four-point compass roses for navigational maps even though current design decisions have moved away from the elaborate four- and eight-point compass roses that were in vogue in previous centuries.

Another important message concerns whether features are labeled, then participants will be free to identify and use these features with certainty. This is perhaps the reason why there were differences between landmark usage between the map types. The image test groups did not have any labeled cues to help them, so each participant had to develop a strategy to describe the route. The map overlay groups, where the landmarks were not labeled, did not use the landmarks because the participants did not need to. There were enough labeled cues, such as street names, to be used to describe the route. The map groups, where landmarks were labeled, showed the greatest number of landmarks described and by more females than males. There were enough cues to describe the route. What is important was the landmarks could be used with certainty, there was no interpretation or guessing what the object was.

The last important issues is that humans tend to use landmarks when describing routes whether verbal or written instructions. Much research has gone in to why this is important for route descriptions (Allen, 1997, 2000; Couclelis et al., 1987; Denis et al., 1999; Lovelace et al., 1999; Michon and Denis, 2001; Tversky and Lee, 1999). Allen (2000) and Couclelis et al. (1987) note that landmarks are important at the start and end of routes to situate the wayfinder in the environment and help navigate to the end point. Michon and Denis (2001) recommend that good route descriptions have landmarks at critical choice points ensure wayfinders are on the correct path; however, Lovelace et al. (1999) did not come to the same conclusions in their research. The results from the current experiments support Michon and Denis (2001) that participants described landmarks more frequently at the critical choice points where there was a change in direction. If previous research shows that landmarks are used in route descriptions from human subjects testing, then why are landmarks not included in computer generated directions?

Current Internet mapping applications do not include landmarks as basic spatial information descriptors in their route descriptions (i.e. Google Maps, Microsoft Bing). Environmental Systems Research Institute (ESRI) ArcGIS 10.0 Network Analyst extension uses topologically-based classes of objects such as edges, junctions, and turn features. The edges form the linear features, junctions are the point features, and turns are the obvious. These three elements form the topologically-integrated network graph. All network graphs have a starting and ending node, a point feature. Point features can and usually contain attribute data. Thus point feature attributes can conceivably be used as landmarks in a network algorithm. Unfortunately, this is not the case in current network algorithms.

If we consider the prospect of identifying attribute information for the nodes, or junctions, then what attribute information would be the most basic? Clearly a street intersection is a nodal feature in a topologically-integrated network system. This feature is connected to the edges. A definition of a landmark is an intersection (Denis et al., 1999). Yet large objects such as buildings are considered landmarks (Lynch, 1960). Can the inclusion of large objects "near" these junctions form the basis of including the junction attribute data? Thus a philosophical GIS question is posed, that of what constitutes "near"? These large objects can be, and usually are independent of, a strict topologically-based network graph; thus the problem of including graphic objects that are not part of a network algorithm, and thusly, a topological data structure. Research shows humans use landmarks for describing routes, whether by verbal, written, or cartographic means; yet computer-generated network algorithms do not.

Allen (1997) advises that basic research regarding the "best" method of conveying spatial information, whether verbal and/or cartographic instructions, should be conducted in light of route direction technologies such as on-board vehicle navigation systems (p. 369). Couclelis and Gottsegen (1997) cautioned that the geometric primitive forms used in GIS, such as points, lines, polygons, areas, and planes do not have the one-to-one correspondence to behavioral geography of landmarks, paths, districts, and environments (p. 154). Therefore, continuing research should be conducted to determine best practices—whether machine generated or natural language—for route descriptions in a digital environment.

Mark, Gould, and McGranaghan (1987) identified many possibilities for using on-board vehicle navigation systems, or their term "vehicle navigation appliance (VNA)" (p. 215), one of which is the inclusion of landmarks for computer-generated route descriptions. However, the authors cautioned the inclusion of landmarks, and other route descriptors, should be used with the full understanding of human spatial cognition as well as identifying a Geographic Information Science initiative to formalize cognitive spatial relations into computational models (Mark, Freksa, Hirtle, Lloyd, and Tversky, 1999).

CHAPTER V

CONCLUSION

The purpose of the research project was to determine if map type, and not sex, influences landmark usage for route descriptions. The pilot experiment showed preliminary results that contradict research literature that states females use landmarks more frequently than males. Statistically significant results were seen based on map type where the least amount of landmarks used was the map overlay, and the map and image test graphic groups described more landmarks. No statistically significant results were seen between the sexes. No statistically significant differences were seen between males and females and their spatial description strategies. In fact, both groups described the routes using a mixture of survey and route knowledge.

Given the preliminary nature of Experiment 1, a second experiment was conducted using a different test participant pool. Modifications were made for Experiment 2, where a fourth test graphic was introduced to discern whether there could be subtle differences between a map overlay with landmarks labeled and not labeled. Statistically significant results similar to Experiment 1 were seen with Experiment 2 where map type determined landmark usage. Once again, the map overlay without landmark labels showed the least amount of landmarks described; and the image, map overlay with labels, and map showed similar results where more landmarks were described more.

Same as Experiment 1, there was no difference between males and females when using landmarks. The results for route description strategies were similar to Experiment 1 where the majority of test participants used mixed methods of route descriptions. In fact, two females used survey-knowledge when describing the test route in the image test graphic group. Also by explicitly asking participants whether they frequently use landmarks for verbal or written communication showed no statistically significant results. The results of the experiments show map type influences whether landmarks will be used for route descriptions. These results address the very nature of whether a researcher can take the concept of a map for granted given different results using different test graphics.

REFERENCES CITED

Allen, G. L. (1997). From knowledge to words to wayfinding: Issues in the production and comprehension of route directions. In *Spatial Information Theory: A Theoretical Basis for GIS*, Volume 132, pp. 363–372. Berlin: Springer. doi: 10-1007/3-540-63623-4_61.

Allen, G. L. (2000). Principles and practices for communicating route knowledge. *Applied Cognitive Psychology 14*, 333–359.

Bagro, L. (1964). *History of cartography*. Cambridge, MA: Harvard University Press.

Barkowsky, T. and C. Freksa (1997). Cognitive requirements on making and interpreting maps. *Lecture Notes in Computer Science* (1329), 347–361.

Berendt, B. and P. Jansen-Osmann (1997). Feature accumulation and route structuring in distance estimation: An interdisciplinary approach. *Lecture Notes in Computer Science* (1329), 279–296.

Bigel, M. G. and C. G. Ellard (2000). The contribution of nonvisual information to simple place navigation and distance estimation: An examination of path integration. *Canadian Journal of Experimental Psychology—Revue Canadienne de Psychologie Experimentale 54*, 172–185. doi: 10.1037/h0087339.

Blades, M. and L. Medlicott (1992). Developmental differences in the ability to give route directions from a map. *Journal of Environmental Psychology 12*, 175–185. doi: 10.1016/S0272-4944(05)80069-6.

Börner, K. (2010). *Atlas of Science: Visualizing what we know*. Cambridge, MA: The MIT Press.

Bosco, A., A. M. Longoni, and T. Vecchi (2004). Gender effects in spatial orientation: Cognitive profiles and mental strategies. *Applied Cognitive Psychology 18*, 519–532. doi: 10.1002/acp.100.

Cameron, R. (1979). *Above Washington: A collection of nostalgic and contemporary aerial photographs of the District of Columbia*. San Francisco: Cameron.

Choi, J. and I. Silverman (2003). Processes underlying sex differences in route-learning strategies in children and adolescents. *Personality and Individual Differences 34*, 1153–1166. doi: 10.1016/S0191-8869(02)00105-8.

Cohen, J. (1992). A power primer. *Psychological Review 112*, 155–159.

Costello, A. B. and J. W. Osborne (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation 10*, 1–9.

Couclelis, H., R. G. Golledge, N. D. Gale, and W. R. Tobler (1987). Exploring the anchor-point hypothesis of spatial cognition. *Journal of Environmental Psychology 7*, 99–122.

Couclelis, H. and J. Gottsegen (1997). What maps mean to people: Denotation, connotation, and geographic visualization in land-use debates. *Lecture Notes in Computer Science* (1329), 151–162. doi: 10.1007/3-540-63632-4_48.

Dabbs, Jr., J. M., C. E. Lee, R. A. Strong, and R. Milun (1998). Spatial ability, navigation strategy, and geographic knowledge among men and women. *Evolution and Human Behavior 19*, 89–98. doi: 10.1016/S1091-5138(97)00107-4.

Daniel, M.-P. and M. Denis (2004). The production of route directions: Investigating conditions that favour conciseness in spatial discourse. *Applied Cognitive Psychology 18*, 57–75.

Daniel, M.-P., A. Tom, E. Manghi, and M. Denis (2003). Testing the value of route directions through navigational performance. *Spatial Cognition and Computation 3*, 269–289.

Davies, C. (2002). When is a map not a map? Task and language in spatial interpretation with digital map displays. *Applied Cognitive Psychology 16*, 273–286. doi: 10.1002/acp.786.

Denis, M., F. Pazzaglia, C. Cornoldi, and L. Bertolo (1999). Spatial discourse and navigation: An analysis of route directions in the city of Venice. *Applied Cognitive Psychology 12*, 145–174. doi: do10.1002/(SICI)1099-0720(199904)13:2<145::AID-ACP550>3.0.CO;2-4.

Evans, G. W. and K. Pezdek (1980). Cognitive mapping: Knowledge of real-world distance and location information. *Journal of Experimental Psychology: Human Learning and Memory 6*, 13–24. doi: 10.1037/0278-7393.6.1.13.

Fontaine, S. and M. Denis (1999). The production of route instructions in underground and urban environments. *Lecture Notes in Computer Science* (1661), 84–94.

Gale, N., R. G. Golledge, J. W. Pellegrino, and S. Doherty (1990). The acquisition and integration of route knowledge in an unfamiliar neighborhood. *Journal of Environmental Psychology 10*, 3–25. doi: 10.1016/S0272-4944(05)80021-0.

Galea, L. A. M. and D. Kimura (1993). Sex differences in route learning. *Personality and Individual Differences 14*, 53–65. doi: 10.1016/0191/8869(93)90174-2.

Gilmartin, P. P. and J. C. Patton (1984). Comparing the sexes on spatial abilities—Map-use skills. *Annals of the Association of American Geographers 74*, 605–619.

Golledge, R. G., A. J. Ruggles, J. W. Pellegrino, and N. D. Gale (1993). Integrating route knowledge in an unfamiliar neighborhood: Along and across route experiments. *Journal of Environmental Psychology 13*, 293–307. doi: 10.1016/S0272-4944(05)80252-X.

Golledge, R. G. and A. N. Spector (1978). Comprehending the urban environment: Theory and practice. *Geographical Analysis 10*, 403–426.

Golledge, R. G. and R. J. Stimson (1997). *Spatial Behavior: A geographic perspective*. New York: The Guilford Press.

Greenhood, D. (1964). *Mapping*. Chicago: University of Chicago Press.

Harley, J. B. (1989). Deconstructing the map. *Cartographica 26*, 1–20.

Hegarty, M., A. E. Richardson, D. R. Montello, K. Lovelace, and I. Subbiah (2002). Development of a self-report measure of environmental spatial ability. *Intelligence 30*, 425–447.

Holding, C. S. and D. H. Holding (1989). Acquisition of route knowledge by males and females. *The Journal of General Psychology 116*, 29–41. doi: 10.1018/00221309.1989.9711108.

Honda, A. and Y. Nihei (2003). Empathy, spatial and verbal abilities characterize one who can best describe a route. *Perceptual and Motor Skills 96*, 861–866.

Horsfall, B. (1997). Tactile maps: New materials and improved designs. *Journal of Visual Impairement and Blindness 91*(1), 61. Retreived August 24, 2011 from Academic Search Premier, EBSCO host.

Keppel, G., J. W. H. Saufley, and H. Tokunaga (1992). *Introduction to design and analysis: A student's handbook*, Volume 2nd. New York: W. H. Freeman and Company.

Kimerling, A. J., A. R. Buckley, P. C. Muehrcke, and J. O. Muehrcke (2009). *Map use: Reading and analysis* (6th ed.). Redlands, CA: ESRI Press.

Kitchin, R. and M. Dodge (2007). Rethinking maps. *Progress in Human Geography 31*, 331–344. doi: 10.1177/0309132507077082.

Kitchin, R. M. (1996). Are there sex differences in geographic knowledge and understanding? *Geographic Journal 162*(Part 3), 273–286. Retrieved from stable URL: http://www.jstor.org/stable/3059650.

Koláčný, A. (1977). Cartographic information—A fundamental concept and term in modern cartography. In L. Guelke (Ed.), *Cartographica*, Number 19, pp. 39–45. Toronto: University of Toronto Press.

Kraak, J. M. and F. Ormeling (2010). *Cartography: Visualization of spatial data* (3rd ed.). New York: The Guilford Press.

Krauth, J. (2000). *Experimental design: A handbook for medical and behavioral research*. New York: Elsevier Science & Technology. Retrieved from http://site.ebrary.com.libaccess.sjlibrary.org/lib/sjsu/docDetail.action?docID=10041461.

Lawrence, M. M., N. Martinelli, and R. Nehmer (2009). A haptic soundscape map of the University of Oregon. *Journal of Maps 5*(1), 19–29. doi: 10.4113/jom.2009.1028.

Lawton, C. A. (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles 30*, 765–779. doi: 10.1007/BF01544230.

Lawton, C. A. (2001). Gender and regional differences in spatial referents used in direction giving. *Sex Roles 44*, 321–337.

Levine, M., I. Janovic, and M. Palij (1982). Principles of spatial problem solving. *Journal of Experimental Psychology: General 111*, 157–175. doi: 10.1037/0096-3445.111.2.157.

Lobben, A. K. and M. M. Lawrence (2012). The use of environmental features on tactile maps by navigators who are blind. *The Professional Geographer 64*, 95–108. doi: 10.1080/00330124.2011.595619.

Lovelace, K. L., M. Hegarty, and D. R. Montello (1999). Elements of good route directions in familiar and unfamiliar environments. *Lecture Notes in Computer Science* (1661), 66–82. doi: 10.1.1.167.8399.

Lynch, K. (1960). *The Image of the City*. Cambridge, MA: MIT Press.

MacEachren, A. (2004). *How maps work: Representations, visualization, and design*. New York: The Guilford Press.

MacFadden, A., L. Elias, and D. Saucier (2003). Males and females scan maps similarly, but give directions differently. *Brain and Cognition 53*, 297–300. doi: 10.1016/S0278-262(03)001 30-1.

Mark, D. M., C. Freksa, S. C. Hirtle, R. Lloyd, and B. Tversky (1999). Cognitive modes of geographical space. *International Journal of Geographical Information Science 13*, 747–774.

Mark, D. M., M. D. Gould, and M. McGranaghan (1987). Computerized navigation assistance for drivers. *The Professional Geographer 39*, 215–220.

Michon, P.-E. and M. Denis (2001). When and why referring to visual landmarks in direction giving? In D. R. Montello (Ed.), *Spatial Information Theory: Foundations of Geographic Information Science*, pp. 292–305. Berlin: Springer. doi: 10.1007/3-540-45424-1_20.

Miller, L. K. and V. Santori (1986). Sex-differences in spatial abilities: Strategic and experiential correlates. *Acta Psychologica 62*, 225–235.

Montello, D. R. (1997). The perception and cognition of environmental distance: Direct sources of information. *Lecture Notes in Computer Science* (1329), 298–311.

Montello, D. R. (1998). A new framework for understanding the aquisition of spatial knowledge in large-scale environments. In M. J. Egenhofer and R. G. Golledge (Eds.), *Spatial and Temporal Reasoning in Geographic Information Systems*, pp. 143–154. New York: Oxford University Press. Retrieved September 15, 2007 http://geog.ucsb.edu/ montello/pubs/microgenesis.pdf.

Neilson, W. A., T. A. Knott, and P. W. Carhart (Eds.) (1934). *Webster's new international dictionary* (2nd ed.). Springfield, MA: G. and C. Merriam.

O'Laughlin, E. M. and B. S. Brubaker (1998). Use of landmarks in cognitive mapping: Gender differences in self report versus performance. *Personality and Individual Differences 24*, 595–601. doi: 10.1016/S0191-8869(97)000237-3.

Piaget, J. and B. Inhelder (1967). *The Child's Conception of Space*. New York: Norton.

Robinson, A. H., J. L. Morrison, P. C. Muehrcke, A. J. Kimerling, and S. C. Guptill (1995). *Elements of Cartography* (6th ed.). New York: John Wiley and Sons.

Robinson, A. H. and B. B. Petchenik (1975). *The Nature of Maps*. Chicago: University of Chicago Press.

Schneider, L. and H. Taylor (1999). How do you get there from here? Mental representations of route descriptions. *Applied Cognitive Psychology 13*, 415–441.

Sherman, J. C. (1976). Large map of the Metropolitan Washington, DC area. braille map, University of Washington, Seattle, WA.

Siegel, A. W. and S. H. White (1975). *Advances in Child Development and Behavior*, Chapter The development of spatial representations of large-scale environments, pp. 9–55. New York: Academic Press.

Sorrows, M. E. and S. C. Hirtle (1999). The nature of landmarks for real and electronic spaces. *Lecture Notes in Computer Science* (1661), 38–50.

Tamhane, A. C. (1979). A comparison of procedures for multiple comparisons of means with unequal variances. *Journal of the American Statistical Association 74*, 471–480. Retrieved from http://www.jstor.org/stable/2286358.

Taylor, H. A. and B. Tversky (1992). Spatial mental models derived from survey and route descriptions. *Journal of Memory and Language 31*, 261–292. doi: 10.1016/0749-596X(92)90014-O.

Thompson, D. (1963). New concept: Subjective distance-store impressions affect estimates of travel time. *Journal of Retailing 39*, 1–6.

Thompson, M. M. (1988). *Maps for America* (3rd ed.). Washington, DC: U. S. Government Printing Office.

Thorndyke, P. W. and B. Hayes-Roth (1982). Differences in spatial knowledge acquired from maps and navigation. *Cognitive Psychology 14*, 560–589. doi: 10.1016/0010-0285(82)90019-6.

Thrower, N. J. W. (2007). *Maps and civilization: Cartography in culture and society* (3rd ed.). Chicago: The University of Chicago Press.

Tom, A. and M. Denis (2004). Language and spatial cognition: Comparing the roles of landmarks and street names in route instructions. *Applied Cognitive Psychology 18*, 1213–1230.

Tversky, B. and P. U. Lee (1999). Pictorial and verbal tools for conveying routes. *Lecture Notes in Computer Science* (1661), 51–64.

Ward, S. L., N. Newcombe, and W. F. Overton (1986). Turn left at the church, or three miles North: A study of direction giving and sex differences. *Environment and Behavior 18*, 192–213.

Wood, D. (2010). *Rethinking the power of maps*. New York: The Guilford Press. Retreived October 11, 2011 from Ebook Library.